Protecting The Waters
of
Nahanni National Park Reserve, N.W.T

Environment Canada
Conservation and Protection
Canadian Parks Service

Environnement Canada
Conservation et Protection
Service canadien des parcs

Canada

Protecting The Waters of Nahanni National Park Reserve, N.W.T.

December 1991

N.W.T. Programs
Inland Waters Directorate
Conservation & Protection
Western & Northern Region
and
Nahanni National Park Reserve
Canadian Parks Service
Prairie & Northern Region

Environment Canada

C & P - IWD - NWT - 91 - 002
TR91 - I / NAH

93-01677/

Cover photograph: Virginia Falls on the South Nahanni River

Photograph by : Lorne Smith

Photograph courtsey of:

Culture and Communications
Government of the Northwest territories

Copies of this report are available from:

Chief, NWT Programs
Inland Waters Directorate
Conservation & Protection
Western and Northern Region
Environment Canada
P.O. Box 2970
Yellowknife, NWT
X1A 2R2

Printed by Artisan Press Ltd., Yellowknife, N.W.T.

EXECUTIVE SUMMARY

The challenges of water resource protection and management that have plagued southern Canada and indeed much of the world are only now starting to be considerations in the north and specifically in the South Nahanni River basin. There is still time to apply lessons learned elsewhere from the many examples of resource degradation due to encroaching development. Nahanni National Park Reserve is located in the downstream reach of the South Nahanni River basin. Current and potential mining development on tributaries of the South Nahanni raise concerns regarding the possible degradation of Park waters and the need to actively preserve the water in its current state.

Baseline water quality data were collected throughout the Park. The Park water is considered to be pristine or very close to pristine. Short and long term water quality objectives were developed to provide water managers with a measure for assessing any changes that may occur in the waters that are beyond the bounds of natural variability. A monitoring program will provide the water quality data necessary for evaluating compliance with the water quality objectives. It is imperative for the preservation of the Park waters that the water quality objectives be incorporated into the water management plans of the Park and the entire South Nahanni watershed. It is also essential that water quality monitoring be increased if the pace of development in the basin accelerates.

RÉSUMÉ

La protection et la gestion des ressources en eau, défis qui ont rendu la vie difficile aux spécialistes dans le sud du Canada et, en fait, dans la plupart des pays du monde entier, ne font qu'émerger en tant que facteurs à considérer dans le Nord et, plus précisément, dans le bassin de la Nahanni Sud. Il est toujours temps de mettre à profit l'expérience acquise ailleurs à partir des nombreux cas de dégradation des ressources dus au développement qui se fait envahissant. La réserve de parc national Nahanni est située dans la bief en aval du bassin de la Nahanni Sud. Les activités d'exploitation minière qui sont en cours ou qui pourraient être envisagées sur les affluents de la Nahanni Sud suscitent des inquiétudes en ce qui concerne la dégradation possible de l'eau du parc et la nécessité de la préserver activement dans sont état actuel.

Des données de base sur la qualité de l'eau ont été recueillies à la grandeur du parc. L'eau qui s'y trouve est considérée comme étant cristalline ou quasi-cristalline. Des objectifs de qualité de l'eau à court et à long termes ont été établis. Ils constituent, pour les gestionnaires de la qualité de l'eau, un outil leur permettant d'évaluer tout changement qui pourrait se produire dans les eaux au-delà des variations naturelles. Un programme de surveillance leur fournira les données sur la qualité de l'eau dont ils ont besoin pour évaluer la conformité aux objectifs de qualité de l'eau. Afin de préserver les eaux du parc, il est essentiel d'intégrer ces objectifs dans des plans de gestion des eaux du parc et même de tout le bassin de la Nahanni Sud. Il s'avére aussi essentiel d'accroître les activités relatives à la qualité de l'eau si le ryhtme des projects de mise en valeur dans le parc s'accélère.

ACKNOWLEDGEMENTS

The program administrators, Arthur Redshaw, Conservation and Protection, and Steve Langdon, Canadian Parks Service, would like to formally acknowledge the extensive contributions and spirit of cooperation provided by all participants during this three year project. Special mention must be made of Ms. Diane Blachford, Water Quality Branch, Inland Waters Directorate, Regina, Saskatchewan, for coordinating the data analysis and authoring this Report; Mr. Brian Olding, Inland Waters Directorate, Yellowknife, for his dedicated work in project planning and initiation and first and second year implementation; and Mr. Sean Meggs, Senior Park Warden, Nahanni National Park Reserve, for his significant efforts in coordinating the field activities.

Nahanni National Park Reserve

Canadian Parks Service:

C. Alexander
H. Belsaka
C. Blyth
S. Catto
K. Colosimo
R. Davies
W. Groat
M. Johansen
P. Lamb
J. Leggo
M.Murphy
P. Peterson
Y. Rowland
F.Tesou
R. Wickstrom

Inland Waters Directorate

Conservation and Protection:

K. Epp
S. Gammage
G. Gray
M. Holenstein
C. Heron
P. Neil
B. Olding
E. Ongley
C. Page
M. Palmer
J. Peddle
R. Pilling
P. Squires
G. Wright
P.Wood

Northern Affairs Program

Inadian and Northern Affairs Canada:

A. Boyer
J. Ginter
D. Trudeau

TABLE OF CONTENTS

Executive Summary iii

Résumé v

Acknowledgements vii

Table of Contents ix

List of Figures x

List of Tables xi

1.0 Introduction 1

2.0 Nahanni National Park Reserve 3
- 2.1 The Park 3
- 2.2 The Threat 6

3.0 Water Resources Activities 13
- 3.1 Historic Water Studies 13
- 3.2 Parks/Inland Waters Directorate Water Quality Study 14

4.0 Water Quality of the Park 19
- 4.1 Regional Variation 19
- 4.2 Seasonal Variation 23
- 4.3 Significance of Metals 33

5.0 Water Quality Protection 37
- 5.1 Background 37
- 5.2 The Approach 39
- 5.3 Water Quality Objectives 40
- 5.4 Interpretation of the Objectives 44
- 5.5 Application 44

6.0 Water Quality Monitoring 47
- 6.1 Background 47
- 6.2 Required Monitoring 47
- 6.3 Additional Monitoring 48
- 6.4 Implementation Plan 48

7.0 Recommendations 51

8.0 References 53

Appendices 55
- I Memorandum of Understanding - Water Quality Study 55
- II Publications on the Water Resources of the Basin 73
- III Average values of Parameters at Key Sites, and Water Quality Guidelines . . 81
- IV Ninetieth Percentiles of Parameters at Key Sites 85

LIST OF FIGURES

Figure 1.	Nahanni National Park Reserve	4
Figure 2.	Water Cascading over Virginia Falls	5
Figure 3.	Channel Braiding of the South Nahanni River in the Downstream Reaches	5
Figure 4.	Dall Sheep in the Mackenzie Mountains	7
Figure 5.	Canoeing a Reach of the South Nahanni River	7
Figure 6.	Recreational Opportunities in the Park	8
Figure 7.	Mining Claims in the South Nahanni River Basin	10
Figure 8.	Canada Tungsten Mine in the Headwaters of the Flat River	11
Figure 9.	Cadillac Mine, Prairie Creek, May 1987	11
Figure 10.	Water and Suspended Sediment Sampling Sites	15
Figure 11.	Sampling for Suspended Sediments with a Continuous-flow Centrifuge in the Flat River, 1988-1989	18
Figure 12.	On-site Water Quality Analyses during the 1988-1989 Field Study	18
Figure 13.	Concentrations of Non-Filterable Residue, Sulphate and Copper in the South Nahanni River Basin, Spring 1988	pp. 24-25
Figure 14.	Hydrograph for Flat River at the Mouth, 1972-1990	26
Figure 15.	Seasonal Pattern of Conductance, Flat River near the Mouth, 1972-1990	27
Figure 16.	Seasonal Pattern of Conductance, Prairie Creek at the Mouth	27
Figure 17.	Seasonal Pattern of Conductance, South Nahanni River above Nahanni Butte	28
Figure 18.	Seasonal Pattern of Non-Filterable Residue, Flat River near the Mouth, 1972-1990	29
Figure 19.	Seasonal Pattern of Non-Filterable Residue, Prairie Creek at the Mouth	29
Figure 20.	Seasonal Pattern of Extractable Manganese, Flat River near the Mouth, 1972-1990	30
Figure 21.	Seasonal Pattern of Total Zinc, Flat River near the Mouth, 1972-1990	31
Figure 22.	Seasonal Pattern of Total Zinc, South Nahanni River above Nahanni Butte	32
Figure 23.	Seasonal Pattern of Extractable Manganese, Prairie Creek at the Mouth	32
Figure 24.	Seasonal Pattern of Nitrite/Nitrates, Flat River at the Mouth, 1972-1990	33
Figure 25.	Framework for Development of Water Quality Objectives	38
Figure 26.	Historic Mean Discharge and Discharge for the Study Years, Flat River near the Mouth	42

LIST OF TABLES

Table 1.	Historic Studies	13
Table 2.	Water Quality Parameters Analyzed for the 1988-1989 Study	16
Table 3.	Water Quality Results of the Basin-Wide Sampling Study, July 16-28, 1988	20
Table 4.	Total Metal Concentrations on Suspended Sediments	35
Table 5.	Water Quality Objectives for Nahanni National Park Reserve	41
Table 6.	Comparison of Long Term and Special Study Data (Averages), Flat River at the Mouth	43
Table 7.	Percentages of Values Below Detection Limit, Flat River at the Mouth, 1972-90	43

1.0 INTRODUCTION

Nahanni National Park Reserve is Canada's premier wild river national park. Filled with deep canyons, white water, cascading falls, and meandering reaches through channels and bars, the park is renowned for its pristine beauty. The uniqueness of the park waters, as well as other outstanding natural features, is recognized nationally and internationally by its designation as a Canadian Heritage River and as a UNESCO World Heritage Site.

The high quality of the park waters cannot be taken for granted. Nahanni National Park Reserve is located in the lower reaches of the South Nahanni River watershed, and as such is vulnerable to stresses from upstream in the basin. Current and potential mining developments on tributaries of the South Nahanni raise concern regarding the possible effects of the developments on the aquatic ecosystem of the park.

The Canadian Parks Service is responsible for the management and operation of the park. Park policy states that natural resources :

> "will be protected and managed with minimal interference to the natural processes to ensure the perpetuation of naturally evolving land and water environments and their associated species" (Canadian Parks Service 1980:41).

Furthermore, the Park management plan, the guide for administering the resources of Nahanni National Park Reserve, states that the natural hydrological regime and quality of park waters will be preserved by:

> "establishing appropriate management strategies that ensure that no unnatural change in park water quality occurs as a result of stream flow into the park;" and "establishing cooperative water management agreements with adjacent land management agencies to ensure the preservation of the South Nahanni and Flat rivers as free-flowing, unpolluted, wilderness rivers. " (Canadian Parks Service, 1980)

Recognizing that the Park could be adversely affected by upstream developments, Canadian Parks Service realized that comprehensive water quality data and a strategy to prevent degradation of the waters would be required. Therefore, in 1988 Canadian Parks Service signed a Memorandum of Understanding (Appendix I) with Inland Waters Directorate for the purpose of collecting baseline water quality data and developing water quality objectives.

This report is the final product in fulfillment of the terms of the Memorandum of Understanding. The report presents the results of the data collection, the water quality objectives and an environmental monitoring plan for the Park. These will provide the Park with information required for the management of the non-degradation of Park waters.

2.0 NAHANNI NATIONAL PARK RESERVE

2.1 The Park

Nahanni National Park Reserve is a spectacular area in the lower reaches of the South Nahanni River basin of the Northwest Territories (Figure 1). The South Nahanni, draining an area of 35,000 square kilometers, originates in the icefields just east of the Yukon-Northwest Territories boundary. It flows 540 kilometers southeastward, cutting through the Mackenzie Mountains, through the park reserve and into the Liard River, a major tributary of the Mackenzie River system. The region is mountainous with wide valleys, rolling hills, elevated plateaus, karst features and striking canyons. Numerous mineral springs, such as Wildmint and Rabbitkettle Hotsprings, are within the park boundaries.

The Park is a wilderness corridor centered along the South Nahanni and Flat rivers. The South Nahanni is higher in elevation and contains almost all of the glaciers. The Flat is of lower relief and less rugged terrain. Most of the South Nahanni watershed overlies glacial debris and lacustrian deposits. Minor tributaries to the South Nahanni are clear with boulder and gravel channels, while the larger tributaries, draining lower elevations, are more turbid.

The Park transects the Mackenzie Mountains fold and thrust belt. The proterozoic formations consist largely of glaciomarine conglomerates and carbonates. The Cambrian to Early Devonian formations contain lead and zinc occurrences, and silver-lead-zinc veins particularly in the Prairie Creek area. The Late Devonian to Jurassic rocks are dominated by silver deposits, marine carbonates and sandstones, and contain important coal deposits. Tungsten occurrences are associated with intrusions in the northern Cordillera which are of the Early and Mid-Cretaceous age (Hamilton et al., 1988).

The South Nahanni River drops from an elevation of 825 meters to 350 meters above sea level within the Park. Much of the drop (90 meters) is accounted for at Viginia Falls (Figure 2). The rest of the river has a gradient of 1.2 meters per kilometer (Figure 3). Peak flows occur from early to mid June as a result of snowmelt. Discharge declines over the summer, but is significantly influenced by rainfall. The volume of water flowing through the South Nahanni can range from 55 to 1500 cubic meters per second, making the river a noteworthy contributor to the Mackenzie River system.

The vegetation of the Park is characterized by boreal species in the lowlands with transition to alpine tundra at higher elevations. Montane and subalpine zones are the most common with extensive stands of spruce and pine. Diverse habitats support more than 750 plant species, with

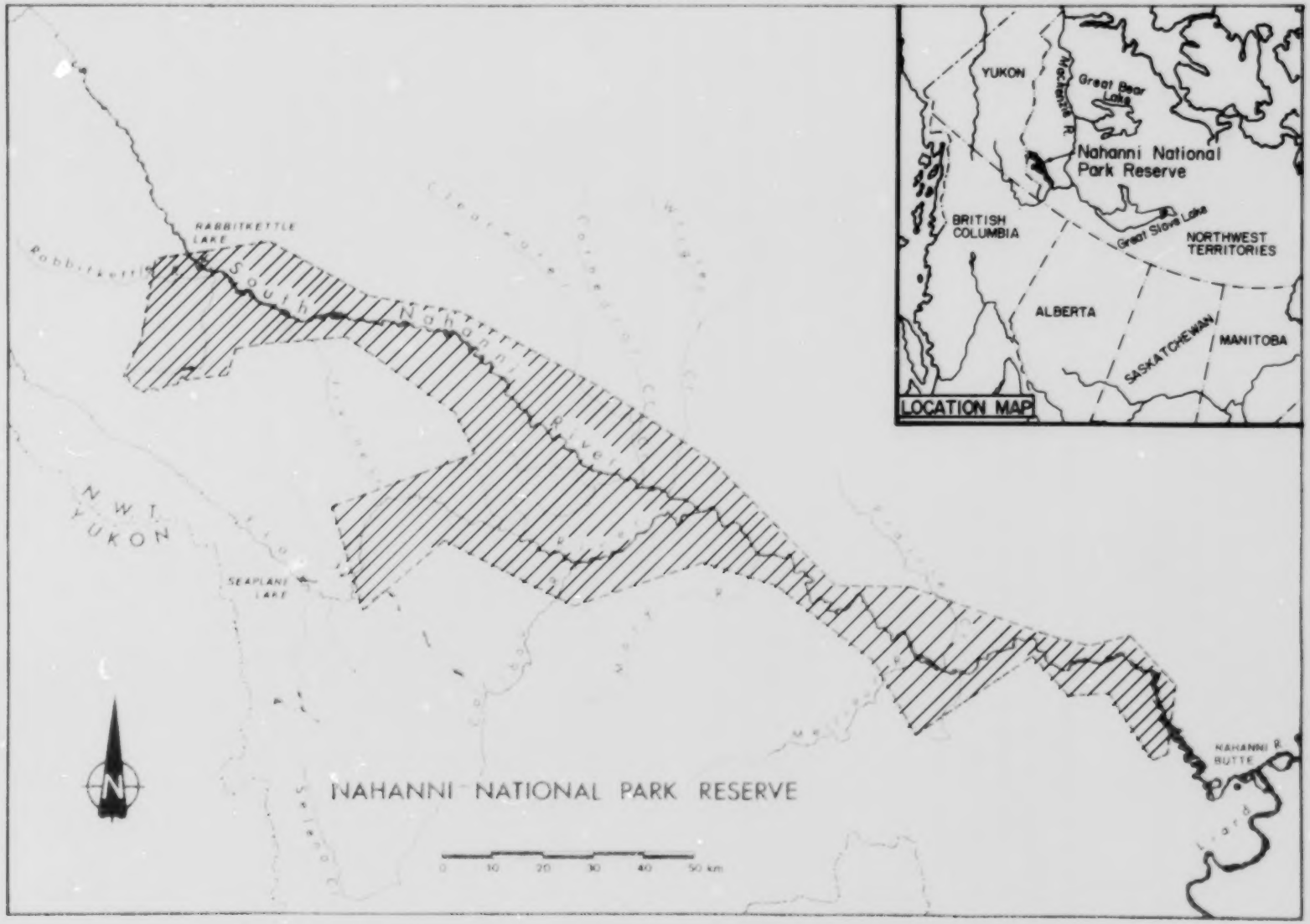


Figure 1. Nahanni National Park Reserve.

Figure 2. Water Cascading over Virginia Falls.

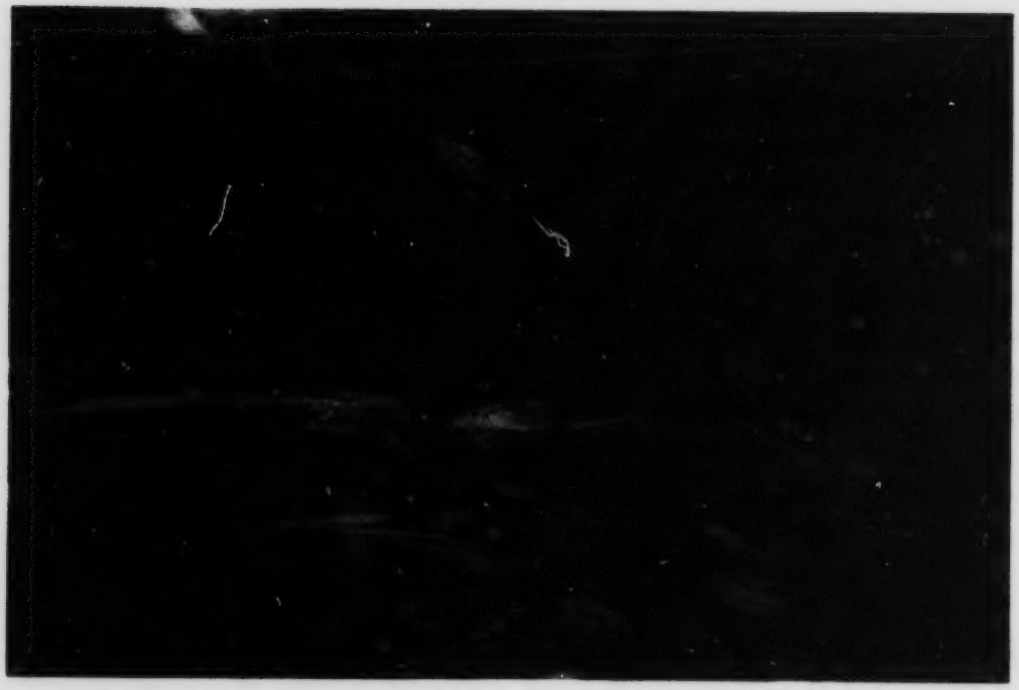


Figure. 3 Channel Braiding of the South Nahanni River in the Downstream Reaches.

40 species not found elsewhere in the Mackenzie Mountains (Canadian Parks Service, 1983). An extensive area of rare orchids exists near Virginia Falls.

A wide diversity of wildlife is found in the Park. More than 120 bird, 40 mammal and 13 fish species inhabit the park. The Flat River and parts of the South Nahanni watershed provide quality moose and deer habitat (Canadian Parks Service, 1983). Woodland caribou occupy valleys at higher elevations throughout the Park. Dall sheep live in the alpine tundra areas, with greatest numbers in the Deadman Valley (Figure 4). Black and grizzly bear, white tail and mule deer are often observed.

The climate of the Park is cold continental with wide monthly temperature and precipitation variations occurring from year to year. Summer and fall are dominated by westerly air currents originating from the Pacific Ocean, while arctic airstreams predominate in winter and spring. The eastern end of the park tends to be wetter and cooler than the western end, and chinook winds are common throughout.

The South Nahanni River is a popular destination for recreation enthusiasts (Figure 5&6). The Park offers outstanding river touring, camping, hiking, and fishing opportunities. Wild river touring by canoe, kayak or raft is by far the most important recreational activity. The South Nahanni River receives almost a thousand visitors a year from all over the world. The short visitor season runs from late June to early September. Optimal travel times on the river are limited to the July to August period due to suitability of water flow.

Access to Nahanni National Park Reserve is limited due to the lack of roads. The Liard Highway is within 64 kilometers of the eastern Park boundary. The tributaries of the upper Nahanni, beyond the Park boundary, can be accessed by the Tungsten and Canol roads. Chartered float planes are the usual mode of access to the Park itself.

The South Nahanni was designated a Park Reserve in 1976 by the Canadian Parks Service. In 1978, the Park was designated a World Heritage Site by UNESCO in order to recognize the river valley as an exceptional natural feature forming part of the heritage of mankind. The river was nominated as a Canadian Heritage River in 1987. Following approval by Environment Canada of a management plan for the Park, and submission of the plan to the Canadian Heritage Rivers Board, the South Nahanni was formally designated as a Heritage River.

2.2 The Threat

The Park has not experienced the traditional level of development that, in other water bodies, has lead to deterioration of water quality. It remains vulnerable, however, to upstream influences outside of the Park boundaries, and to stresses external to the basin. Airborne contaminants are

Figure 4. Dall Sheep in the Mackenzie Mountains. (photo courtesy of G.N.W.T.)

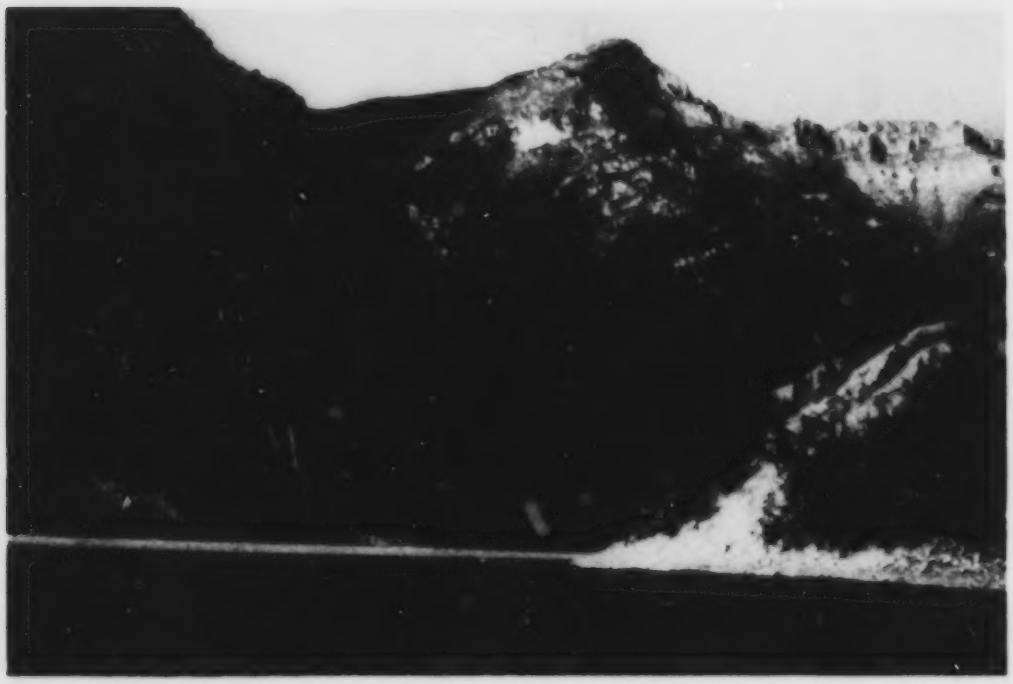


Figure 5. Canoeing a Reach of the South Nahanni River.

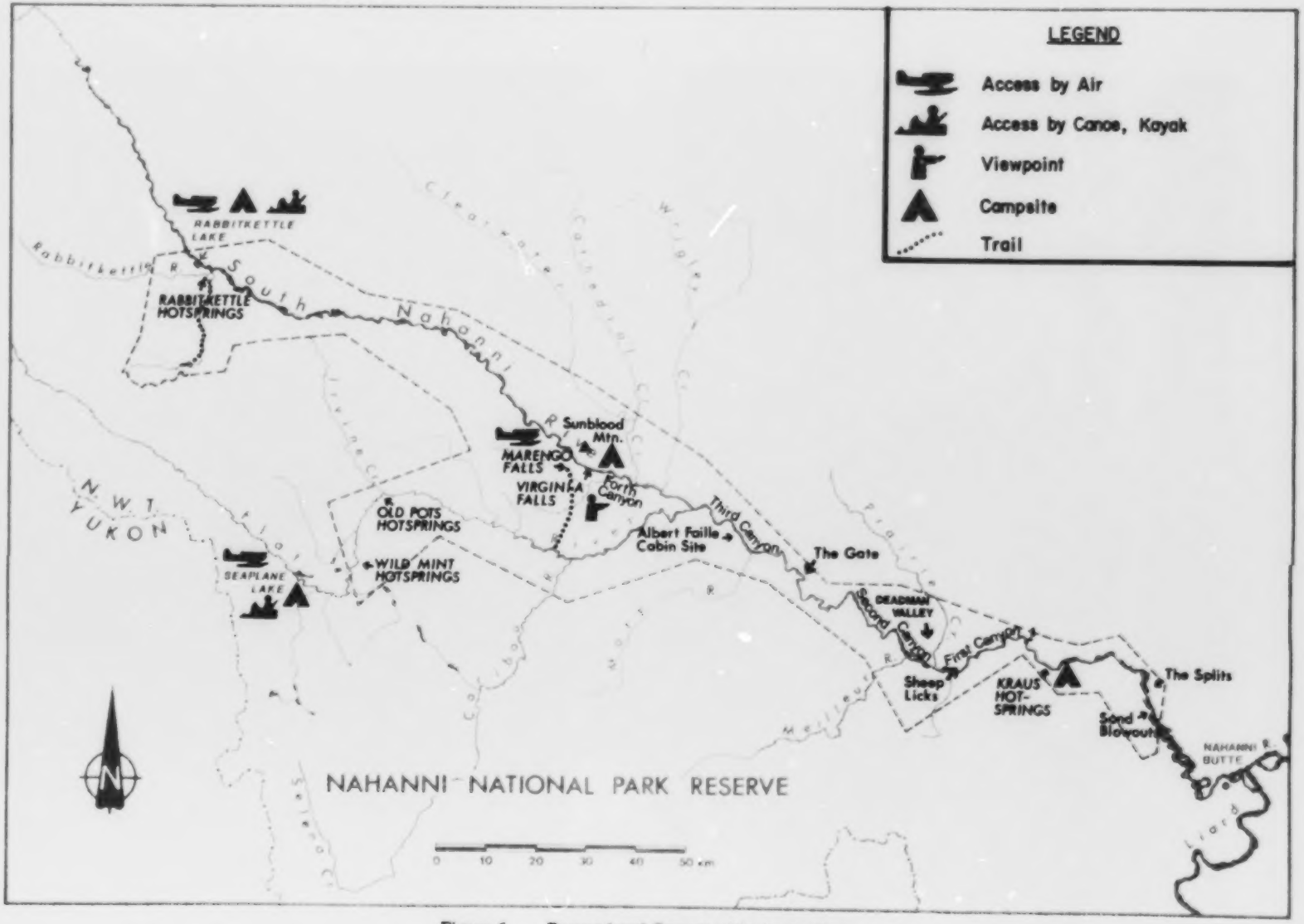


Figure 6. Recreational Opportunities in the Park.

not of immediate concern as quantities are likely to be considerably lower than those from local terrestrial and aquatic sources.

The Park is located in an area rich in tungsten, lead, zinc, copper and silver. The South Nahanni watershed contains numerous mining claims (Figure 7). The infrastructure for two mines just outside of the Park is currently in place. Canada Tungsten Mine (Figure 8) is situated at the headwaters of the Flat River. Cadillac Mine (Figure 9) is located on Prairie Creek approximately 25 kilometers upstream of the confluence with the South Nahanni River.

It appears likely at this time that two other major mining projects will begin once international commodity prices rise. The Union Carbide project on Lened Creek, a tributary of the Little Nahanni River, has completed much of the diamond drilling work with encouraging results. At Howard Pass, a placer mining project for lead, zinc and silver is planned, with a camp to be established in the Northwest Territories and a mine in the Yukon. Existing and future mining developments, therefore, present a potential threat to the quality of Park waters, as the cumulative impact of the mining activities could be considerable.

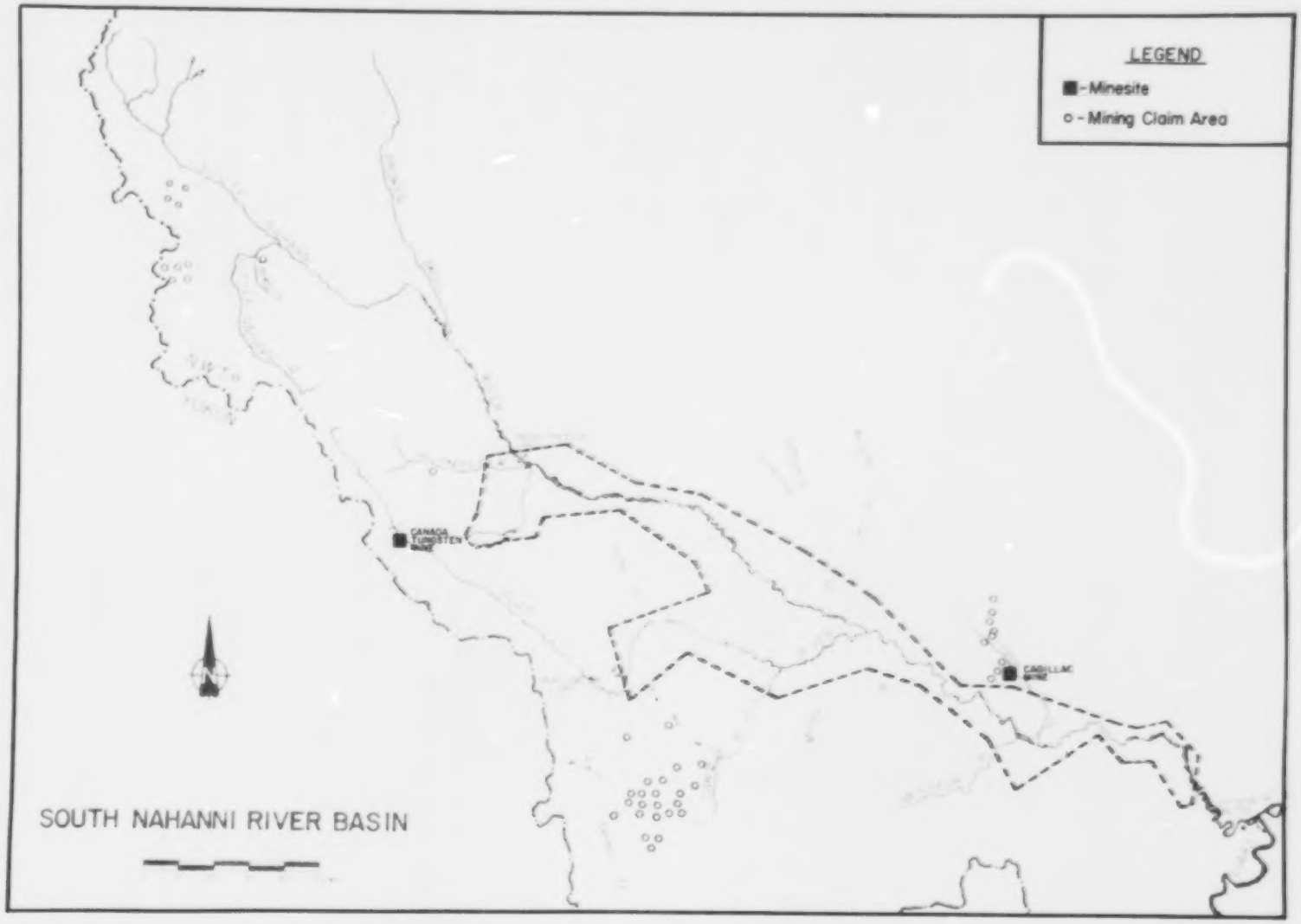


Figure 7. Mining Claims in the South Nahanni River Basin.

Figure 8. Canada Tungsten Mine in the Headwaters of the Flat River.

Figure 9. Cadillac Mine, Prairie Creek, May 1987.

3.0 WATER RESOURCES ACTIVITIES

3.1 Historic Water Studies

The water resources of the Nahanni River basin have been studied by a number of organizations for a variety of purposes. Table 1 is a summary of the various studies which have been carried out on waters in or flowing into Nahanni National Park Reserve. Appendix II is a listing of the publications available on the historic water resources of the basin.

TABLE 1. Historic Studies

Agency/Company		Type of Study	Years of Study
Environment Canada			
Inland Waters		discharge data	1961-present
		water quality data	1966-present
		flood reports and measurements	1972,77,83,86
		flood frequency analysis	1986
		flood risk map (Nahanni Butte)	1987
		hydrology & water chemistry	1975-77 (1981)
Canadian Parks Service		water chemistry	1975, 82
		geomorphology	1972,73(74,75)
		storm run-off effects	1980
		biophysical resources	1979
		resource description	1984
Enviromental Protection (Cantung/Flat River)		water quality	1973. 78
		acute toxicity tests	1975, 76
		metal levels in fish	1977
		aquatic ecosystem	19778
Canadian Wildlife Service		limnological survey	1975-76(77), 78(79), 81
		fish & sediment analysis	1961
		ecology	1971
Indian and Northern Affairs Canada		water quality monitoring (Cadillac/Prairie Creek)	1975
		water quality monitoring (Cantung/Flat River)	1974, 83, 84
University	British Columbia	ground water	1964
	McMaster	hydrology & geomorphology	1974, 75, 76, 78, 80, 82
		carbonate water chemistry	1973(74), 82
	Carleton	ground water geochemistry	1987, 88
		stream silt analysis	1988
		ground water/hot springs geochemistry	1990-91
		Rabbit Kettle hot springs baseline study	1991-92
Mines			
Cadillac/consultants (Prairie Creek)		aquatic biology	1981, 82
		water quality	1980
		environment evaluation	1980
Cantung/consultants (Flat River)		water quality	1977
		tailings seepage	1977, 78, 79, 82, 83, 86
		ground water	1977, 78, 83, 86
		aquatic biology	1976, 77, 78
		hydrology	1980
		hydrogeology	1982

NOTE: dates in brackets indicate the year in which a report was published if it is different from the year in which the study took place.

3.2 Parks/Inland Waters Directorate Water Quality Study

The potential increase in mining activity in the South Nahanni River basin raised concerns that the natural, or existing, water quality conditions in the Park could be degraded. This led to the signing of a Memorandum of Understanding (Appendix I) by the Canadian Parks Service and the Inland Waters Directorate to implement a water quality study in Nahanni National Park Reserve.

The Canadian Parks Service, which administers the Nahanni National Park Reserve, identified the establishment of pre-development water quality objectives as a priority for the protection of the Park's aquatic resources. The Northwest Territories division of Inland Waters Directorate, which is responsible for the collection of water quality data for water courses within the Territories, recognized the need to develop water quality objectives, the opportunity to develop monitoring protocols in a cordilleran northern environment, and the necessity of using the objectives and protocols to properly intervene when future mining discharges are being assessed by the Northwest Territories Water Board. The mutual interest in water quality in the Park led to the establishment of a joint water quality study.

The objectives of the study were:

1. To characterize the variability of key components of the water quality regime, focussing on variables associated with the mining industry;

2. To develop water quality objectives for key components of the water quality regime on major streams entering the Park; and

3. To design an on-going water quality monitoring program, to be carried out by Canadian Parks Service, to evaluate compliance with the water quality objectives (Olding and Palmer, 1989).

Thirteen sampling sites were selected to provide representative data for the South Nahanni River and those tributaries which could potentially be affected by upstream mining development. The sites chosen for water quality sample collection are shown in Figure 10.

Sampling took place in the open water seasons of 1988 and 1989. The spring (May 23 - June 11, 1988 and May 24 - June 11, 1989) and fall (September 9 - 28, 1988 and August 31 - September 19, 1989) sampling periods were selected to represent the extremes in variability in concentration of water quality parameters that occur largely in relation to changes in water flow. The spring peak water flow is due to snowmelt from the mountains and orographic rainfall from maritime air masses. Water flows are nearing their lowest levels in fall, before reaching annual lows at freeze-up. In addition to the spring and fall sampling, the thirteen water quality sites

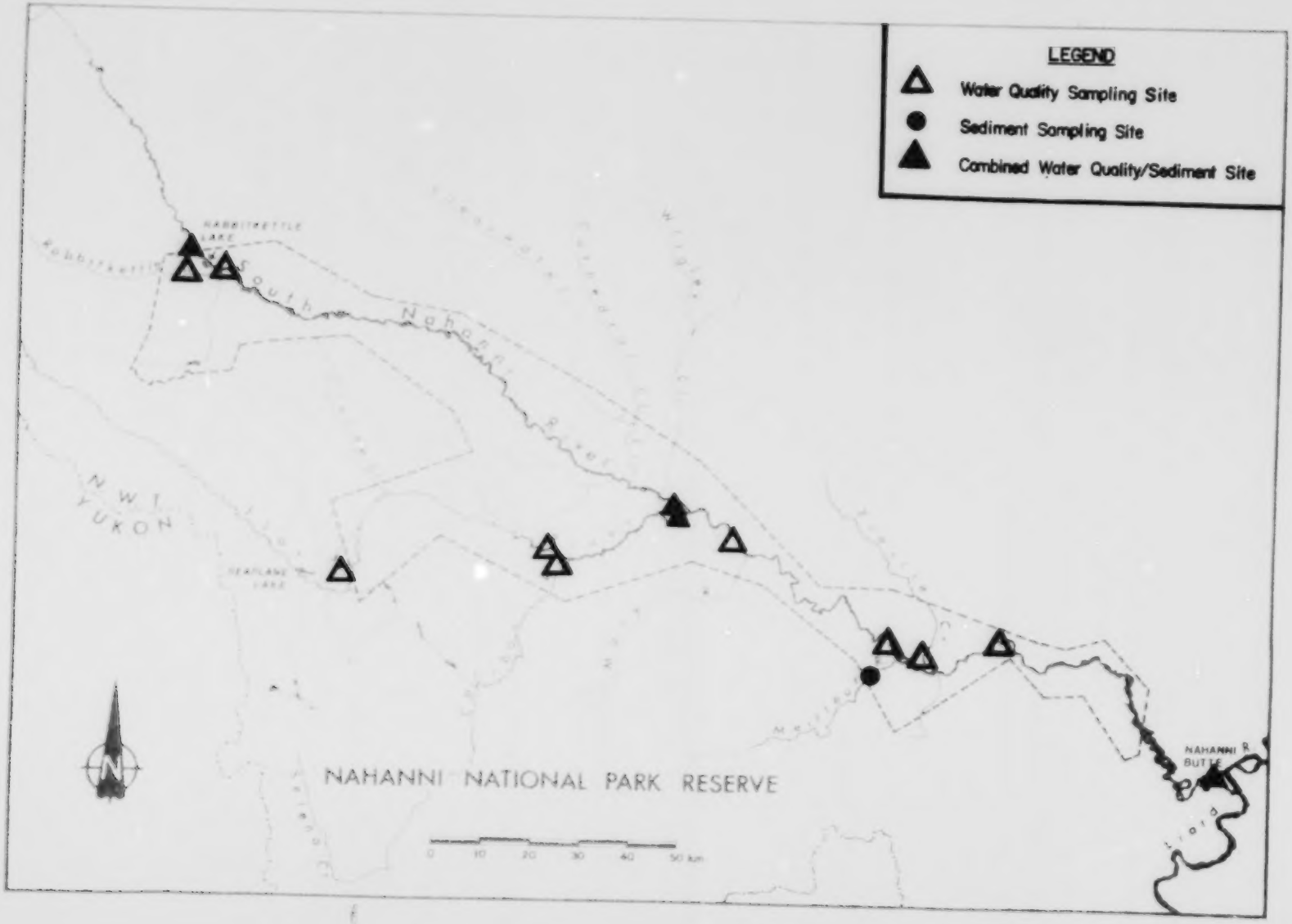


Figure 10. Water and Suspended Sediment Sampling Sites.

were sampled at variable frequencies throughout the open water periods depending upon logistic feasibility.

Water quality parameters selected for analyses are those associated with silver and tungsten mining activities. Water samples were therefore analyzed for a wide range of metals, nitrogen compounds (which can be released from blasting operations), sulphates (which can be leached by acid mine drainage), and various physical and chemical parameters. The latter are necessary to aid in the interpretation of the metal results and of the general water quality in the basin. The complete list of parameters analyzed is shown in Table 2.

TABLE 2. Water Quality Parameters Analyzed for the 1988-1989 Study

Field Physicals	Laboratory Physicals
Conductance	Non-filterable Residue
Turbidity	
Temperature	
pH	

Nutrients	Major Ions
Nitrites/Nitrates	Sulphate
Total Ammonia	

Dissolved Metals	Extractable Metals	Total Metals
Manganese	Manganese	Cyanide
Iron	Iron	Vanadium
Cobalt		Cobalt
Nickel		Nickel
Copper		Copper
Zinc		Zinc
Arsenic		Cadmium
Selenium		Barium
Cadmium		Lead
Barium		
Lead		

All of the water samples collected for metal analyses were analysed for "total" metals. This means that all of the metals (particulate and in solution) in an unfiltered water sample were determined. At some sites, "dissolved" metals were also measured; this is the concentration of metals present in a filtered sample. The dissolved measure is generally considered to be a more accurate estimate of the amount of metal readily available to aquatic biota, and is therefore of concern for aquatic life protection. The total metal analysis is an estimate of the absolute amount of metal present in the water environment. Metals released from mining activities are present in both particulate and dissolved phases. Logistic constraints prevented collecting and analyzing for dissolved metals at all sites.

Metals are commonly associated with particulate matter in aquatic environments. Sediments were therefore collected and analyzed for a range of metals. Suspended sediments were collected at five sites (Figure 10) with a continuous-flow centrifuge (Figure 11). Suspended rather than bottom sediment was sampled as the metals have greater affinity for the smaller particle sizes which, in the high energy environment of the South Nahanni River, are most likely to be in suspension.

A quality control program was implemented at five sites: Flat River at the mouth, South Nahanni River above and below Rabbitkettle River, South Nahanni River above the Flat River and South Nahanni River above Nahanni Butte. Triplicate samples were collected and analyzed for all parameters during each season of both study years. Duplicate blanks were collected on the same schedule. Triplicates for dissolved metals were collected from the Flat River at the mouth in the fall of 1988.

All aspects of the field studies were carried out cooperatively by wardens of the Canadian Parks Service, staff of the Inland Waters Directorate and field technicians of Indian and Northern Affairs Canada (INAC), Figure 12.

Water quality data were evaluated after the first year (1988) of the study. Modifications were then made to the second year (1989) study design to ensure the program objectives were efficiently met (Olding and Palmer, 1989).

Figure 11. Sampling for Suspended Sediments with a Continous-flow Centrifuge in the Flat River, 1988-1989.

Figure 12. On-site Water Quality Analyses during the 1988-89 Field Study.

4.0 WATER QUALITY OF THE PARK

The South Nahanni River basin may be subjected to extensive natural resource development activity in the next few years. These activities have the potential to adversely affect the water quality of the basin and disrupt the life processes which depend upon it. Knowledge of the water quality dynamics of the river is essential to aid in understanding the aquatic environment and to contribute to effective water management plans so that environmentally sound decisions regarding safe development can be made. Our knowledge of the water quality of the Park, based on the present and historical studies, is summarized here.

4.1 Regional Variation

The basin-wide study conducted from July 1988 to September 1989 permits an assessment of the regional variation in Park waters. Ground and surface water runoff dissolves minerals and nutrients as it passes through the bedrock and surficial deposits of the watershed. Differences amongst the tributaries, and between the tributaries and the mainstem, largely reflect variation in the geology of the area.

The Caribou River and Prairie Creek tributaries are distinctly different in quality compared to the mainstem South Nahanni River. Prairie Creek, flowing through bare upland and steep canyon terrain, carries sediment levels which are an order of magnitude lower than that carried by the mainstem (Table 3). Concentrations of all metals in this tributary are also lower than elsewhere in the Park, as most metals are transported in association with suspended sediments. Levels of dissolved substances, however, are as much as two-fold higher than in the mainstem; this is reflected in elevated levels of calcium, magnesium, sodium and sulphate, likely the result of contributions from mineral springs in the karst area. It is also possible that White Spray Springs, draining the Ram Plateau, may drain underground and influence the dissolved solids levels in Prairie Creek. The creek appears to have little influence on the mainstem, due to the low discharge of Prairie Creek relative to the South Nahanni in July.

The Caribou River is a tributary of the Flat River. The Caribou River has much lower levels of sediment than the Flat or the South Nahanni rivers. The concentration of metals in the river, however, are not as low as would be suggested by the sediment levels. This is likely due to a greater load of metals per unit of sediment emanating from upstream metal deposits. The high level of carbonates, and relatively high levels of calcium and sodium, reflect the carbonate strata in the area and the presence of mineral springs. Comparison of water quality from the Flat River above and below Caribou River (Table 3) reveals that the Caribou has little influence on the quality of the Flat River.

TABLE 3. Water Quality Results of the Basin-Wide Sampling Study, July 16-28, 1988

STATION	Non-Filterable Residue	Turbidity (JTU)	Total Dissolved Solids	Conductance (usie/cm)	Colour (Rel. Units)	Temperature (°C)	pH	Dissolved Organic Carbon	Part. Organic Carbon	Total Organic Carbon	Diss. Sulphate	Diss. Chloride	Diss. Sodium	Diss. Flouride
South Nahanni River above Rabbitkettle River	214	148	98	182	10	10	8.06	1.17	4.93	6.1	20.9	0.4	0.54	0.06
Rabbitkettle River at mouth	304	208	88	159	5	7	8.00	0.961	3.80	4.76	15.1	0.3	0.45	0.05
South Nahanni River below Rabbitkettle River	76	70	97	178	5	13	8.02	1.28	1.37	2.65	21.3	0.2	0.51	0.06
South Nahanni River above Flat River	365	266	109	199	5	14	7.85	1.35	14.1	15.45	19.3	0.2	0.56	0.07
Caribou River at mouth	49.2	50	166	307	20	12	8.01	4.16	0.690	4.85	26.6	0.4	0.80	0.07
Flat River at mouth	303	236	118	214	20	12	8.15	3.56	4.3	7.86	18.6	0.3	0.83	0.07
Flat River above Caribou River	44.4	42	118	217	10	15	7.84	2.11	0.523	2.63	18.4	0.3	1.11	0.08
Flat River at Park Boundary	45.2	25	101	186	10	11	7.83	1.74	0.808	2.55	19.5	0.3	1.02	0.08
South Nahanni River above Mary River	368	260	110	203	10	13	8.10	2.66	8.8	11.46	18.8	0.3	0.58	0.07
South Nahanni River above Meilleur River	601	420	118	217	10	12	8.26	2.06	19.4	21.46	20.6	0.3	0.67	0.08
Prairie Creek at mouth	27.5	25	168	314	5	11	8.25	1.57	1.45	3.02	27.3	0.3	1.01	0.09
South Nahanni River below George's Riffle	610	450	124	225	5	12	8.06	2.29	17.4	19.69	23.3	0.3	0.81	0.08
South Nahanni River below Nahanni Butte	333	304	132	214	20	13	7.9	2.48	6.09	8.57	27.7	0.8	1.47	0.08

NOTE: all parameters in mg/l except where noted.

TABLE 3. Water Quality Results of the Basin-Wide Sampling Study, July 16-28, 1988 con't.

STATION	Diss. Magnesium	Diss. Potassium	Diss. Calcium	Nitrites/ Nitrates	Ammonia	Diss. Nitrogen	Part. Nitrogen	Total Nitrogen	Diss. Phosph.	Part. Phosph.	Total Phosph.	Bicarb-onate	Hardness	Non-carb. Hardness
South Nahanni River above Rabbitkettle River	5.6	0.45	26.5	0.027	0	0.046	0.182	0.23	<0.003	<0.006	--	79.7	89.2	23.8
Rabbitkettle River at mouth	3.1	0.66	25.8	0.077	0	0.100	0.150	0.25	<0.003	0.25	0.252	77.9	77.2	13.3
South Nahanni River below Rabbitkettle River	5.6	0.42	25.6	0.036	0	0.075	0.050	0.13	<0.003	0.065	0.067	80.8	87	20.7
South Nahanni River above Flat River	6.6	0.43	28.6	0.046	0	0.090	0.181	0.27	<0.003	0.191	0.193	100.2	98.6	16.4
Caribou River at mouth	8.8	0.50	48.0	0.047	0	0.135	0.067	0.22	<0.003	0.034	0.036	153.6	156.1	30.1
Flat River at mouth	5.5	0.59	33.5	0.043	0	0.121	0.264	0.39	0.006	0.224	0.230	107.6	106.3	18
Flat River above Caribou River	5.2	0.70	33.7	0.032	0	0.083	0.067	0.15	<0.003	0.033	0.035	108.2	105.6	16.8
Flat River at Park Boundary	4.4	0.57	28.7	0.034	0	0.08	0.081	0.16	<0.003	0.054	0.056	83.6	89.8	21.2
South Nahanni River above Mary River	6.6	0.44	29.7	0.045	0	0.105	0.223	0.33	0.006	0.231	0.237	100.9	101.3	18.5
South Nahanni River above Meilleur River	7.0	0.45	31.5	0.048	0	0.112	0.348	0.46	<0.003	0.31	0.312	108.6	107.5	18.4
Prairie Creek at mouth	15.2	0.25	40.0	0.100	0	0.161	0.027	0.17	<0.003	0.011	0.013	163.3	162.5	28.5
South Nahanni River below George's Riffle	7.5	0.48	32.8	0.055	0	0.108	0.320	0.43	<0.003	0.35	0.352	111.3	112.8	21.5
South Nahanni River below Nahanni Butte	8.0	0.54	34.3	0.054	0	0.112	0.209	0.32	<0.003	0.206	0.208	111.5	118.6	27.1

NOTE: all parameters in mg/l except where noted.

TABLE 3. Water Quality Results of the Basin-Wide Sampling Study, July 16-28, 1988 con't.

STATION	Cyanide	Total Alkalinity	Total Vanadium	Extract. Manganese	Extract. Iron	Total Cobalt	Total Nickel	Total Copper	Total Zinc	Diss. Arsenic	Diss. Selenium	Total Cadmium	Total Barium	Total Lead
South Nahanni River above Rabbitkettle River	<0.001	65.4	0.0005	<0.002	0.138	<0.0005	0.0012	0.0008	0.0026	0.0006	0.0005	0.0001	<0.08	<0.0007
Rabbitkettle River at mouth	0.001	63.9	0.0164	0.141	4.01	0.0034	0.0099	0.0058	0.0518	0.0020	0.0008	0.0007	0.167	0.0040
South Nahanni River below Rabbitkettle River	0.001	66.3	0.0026	0.039	1.13	0.0014	0.0064	0.0025	0.0277	0.0008	0.0005	0.0002	<0.08	0.0019
South Nahanni River above Flat River	0.001	82.2	0.0074	0.112	2.83	0.0022	0.0080	0.0050	0.0372	0.0007	0.0004	0.0004	0.138	0.0048
Caribou River at mouth	0.001	126	0.0023	0.017	0.817	0.0007	0.0080	0.0025	0.0285	0.0004	0.0007	0.0005	0.081	0.0008
Flat River at mouth	0.002	88.3	0.0067	0.110	3.27	0.0028	0.0109	0.0064	0.0438	0.0006	0.0006	0.0007	0.196	0.0038
Flat River above Caribou River	<0.001	88.8	0.0018	0.030	0.798	0.0006	0.0024	0.0018	0.0082	0.0008	0.0003	0.0002	<0.08	0.0015
Flat River at Park Boundary	<0.001	68.6	0.0026	0.032	1.17	0.0010	0.0034	0.0027	0.0143	0.0009	0.0003	0.0002	<0.08	0.0019
South Nahanni River above Mary River	0.001	82.8	0.0073	0.122	3.03	0.0024	0.0096	0.0058	0.0390	0.0007	0.0006	0.0005	0.176	0.0045
South Nahanni River above Meilleur River	0.002	89.1	0.0103	0.167	3.80	0.0033	0.0125	0.0075	0.0521	0.0005	0.0006	0.0008	0.157	0.0064
Prairie Creek at mouth	0.001	134	0.0008	0.014	0.248	<0.0005	0.0014	0.0010	0.0052	0.0002	0.0004	<0.0001	<0.08	0.0008
South Nahanni River below George's Riffle	0.001	91.3	0.0107	0.166	4.25	0.0031	0.0128	0.0077	0.0519	0.0005	0.0006	0.0008	0.254	0.0059
South Nahanni River below Nahanni Butte	0.002	91.5	0.0070	0.110	3.04	0.0028	0.0096	0.0053	0.0377	0.0005	0.0007	0.0005	0.128	0.0036

NOTE: all parameters in mg/l except where noted.

The Flat River shows distinct changes in water quality as it flows from the Park boundary to the confluence with the South Nahanni. The sediment content increases dramatically near the confluence, reflecting the erodible till and lacustrine silts of the glacial sediment valley (Canadian Parks Service, 1983). The metal concentrations parallel the changes in sediment content. The dissolved solid concentration increases only slightly, due largely to increases in calcium. The Flat River flows through areas rich in calcium carbonate-precipitating springs. Comparison of water quality data from the South Nahanni River above the Flat River to data from below the Flat River (South Nahanni River above Mary River, Figure 10, Table 3) shows that the tributary has little, if any, effect on the quality of the mainstem.

The Rabbitkettle River is very similar in quality to the South Nahanni River at the upstream Park boundary (South Nahanni above Rabbitkettle River, Figure 10). Metal concentrations in the Rabbitkettle are slightly higher not only due to a higher sediment content but also to a greater concentration of metals per unit of sediment. Rabbitkettle River flows through a region west of the mainstem which contains granitic intrusions. Higher levels of manganese and zinc, which are evident in the waters of Rabbitkettle River, are characteristic of these intrusions.

Data for all parameters analyzed as part of the basin-wide study show that increases in constituents occur downstream along the South Nahanni River (Table 3). This is supported by the pattern of concentration of sediment, copper and sulphate which was observed in spring 1988 (Figure 13); levels increase only slightly, but variability increases significantly in the downstream direction.

4.2 Seasonal Variation

Concentrations of water quality parameters fluctuate over the hydrologic year. In a basin in which the human sources of water quality substances remain, for the time being, minor, the natural cycles of the substances predominate. Since the Flat River at the mouth site has a relatively continuous and a longer period of record than other sites, it is used here to illustrate seasonal cycles.

The common discharge pattern for the Flat River is one of low flows during the December to April period, followed by rising levels in May due to snowmelt from the low altitudes in the basin (Figure 14). June, July and August show the highest flows, but there is no distinct peak as the time of high level flows varies in response to summer rainfall events. The Flat River has higher levels of flow in September and October than elsewhere in the South Nahanni basin. This reflects the forest cover and retentive soils in the Flat River basin (Canadian Parks Service, 1983) which store water during the summer and release it in the fall.

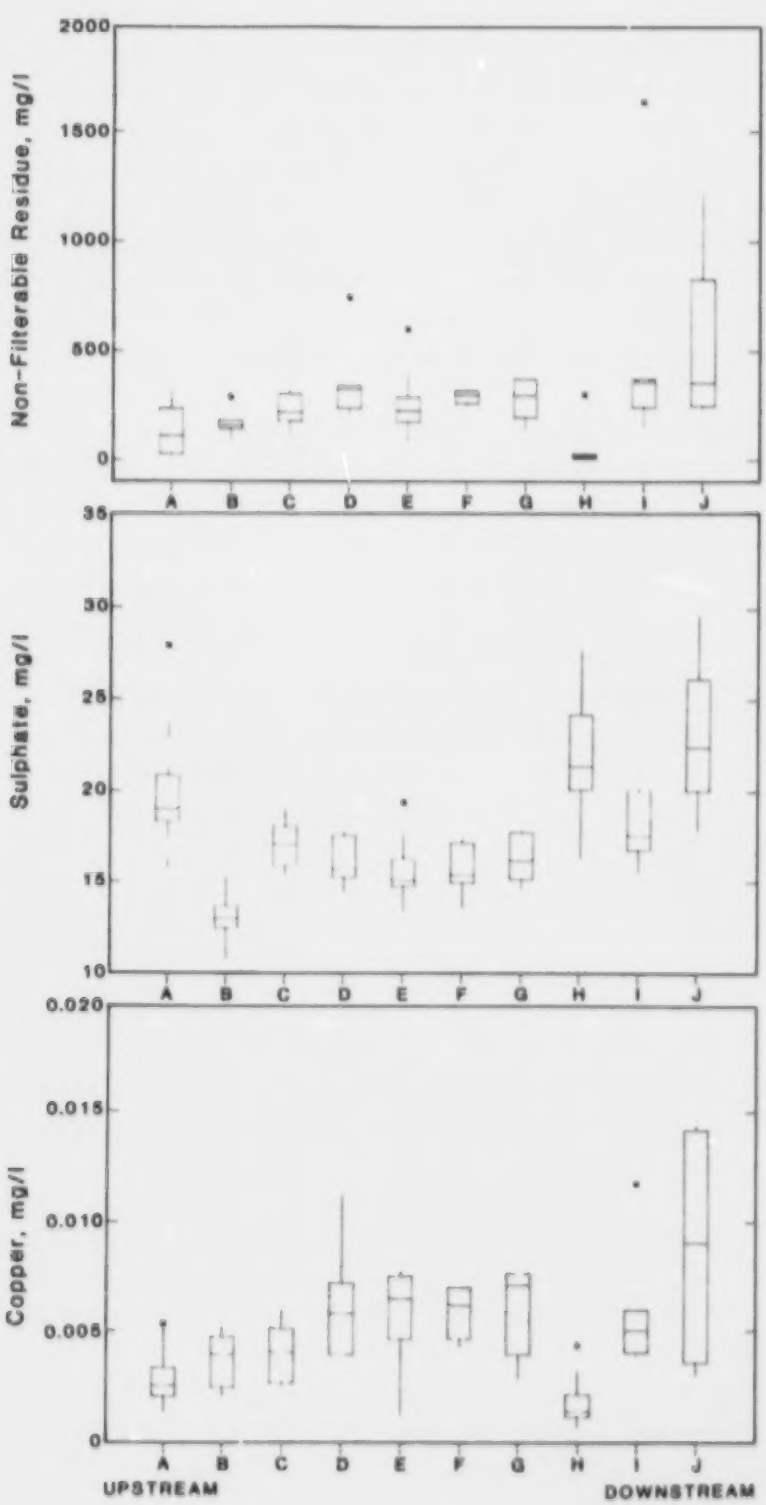


Figure 13. Concentrations of Non-Filterable Residue, Sulphate and Copper in the South Nahanni River Basin, Spring 1988.

Figure 13 - Sample Site Key

A - South Nahanni River above Rabbitkettle River.

B - Rabbitkettle River at Mouth.

C - South Nahanni River below Rabbitkettle River.

D - South Nahanni River above Flat River.

E - Flat River at Mouth.

F - South Nahanni River above Mary River.

G - South Nahanni River above Meilleur River.

H - Prairie Creek at Mouth.

I - South Nahanni River below George's Riffle.

J - South Nahanni River below Nahanni Butte.

Box Whisker Plot Legend

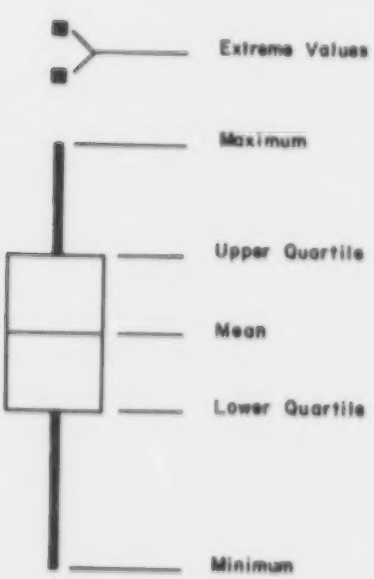


Figure 13. Concentrations of Non-Filterable Residue, Sulphate and Copper in the South Nahanni River Basin, Spring 1988 con't.

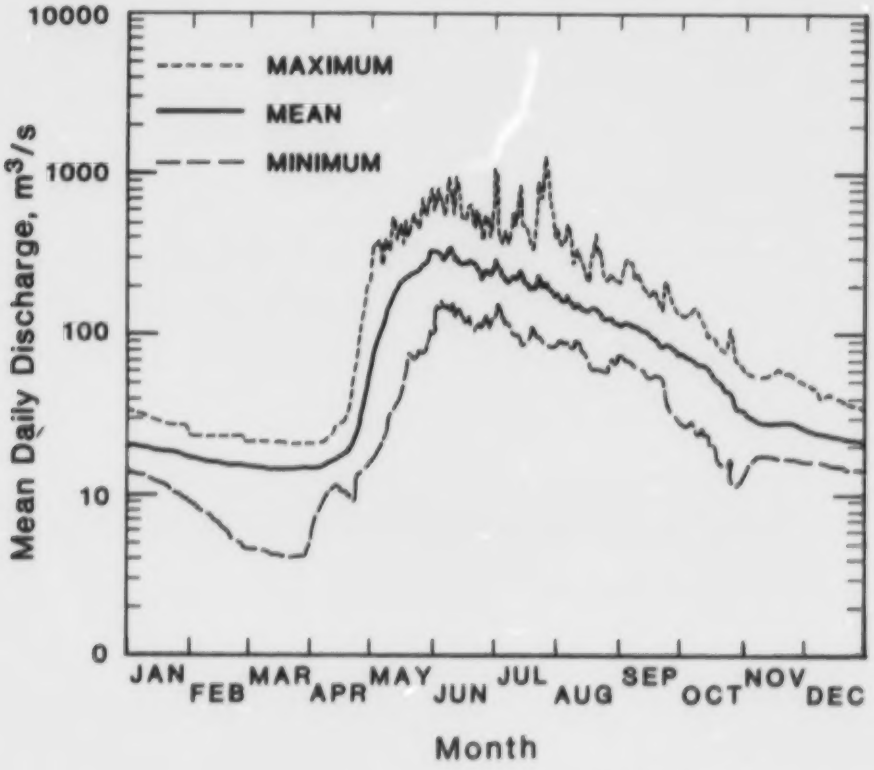


Figure 14. Hydrograph for Flat River at the Mouth, 1972 - 1990.

The water quality parameters that most clearly reflect variations in discharge are conductance and non-filterable residue. Conductance is a measure of dissolved minerals, such as carbonates and sulphates measured in micro siemens per centimeter (μ sie/cm). Throughout the South Nahanni basin, mineral springs contribute these dissolved solids by way of ground and surface water runoff. Conductance in the Flat River (Figure 15) peaks during the winter period, falls with the increase in discharge in May and remains relatively low over the open water season. The inverse relationship between volume of flow and dissolved solids concentration is common world wide. Dissolved minerals are diluted during times of high flow such as heavy rainfall or snowmelt, because an increased proportion of the total flow is routed directly into channels, with little if any contact with soluble minerals in the rock or soils. The inverse trend is also caused by dilution of the baseflow from ground water sources, which supply a significant proportion of the flow during low flow periods.

The same inverse relationship is evident in Prairie Creek (Figure 16), where the distinctly different conductance values for spring and fall reflect the flashy spring discharge from the canyon terrain followed by very low flows for the remainder of the open water season.

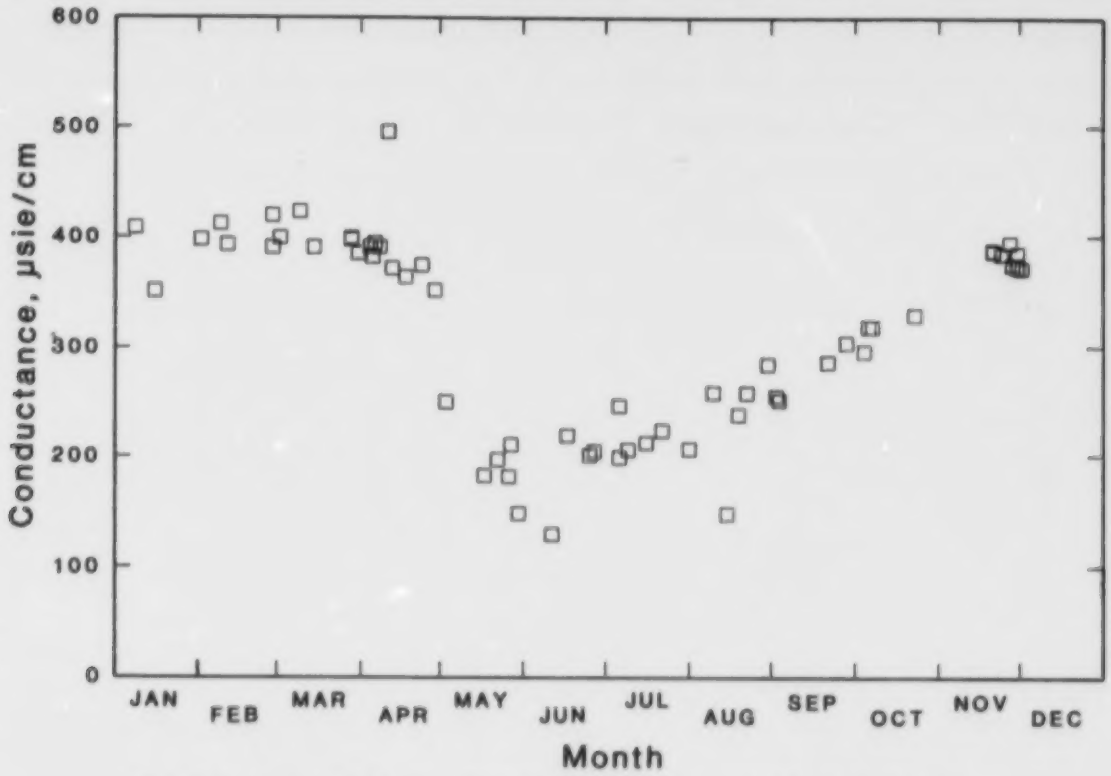


Figure 15. Seasonal Pattern of Conductance, Flat River near the Mouth, 1972-1990.

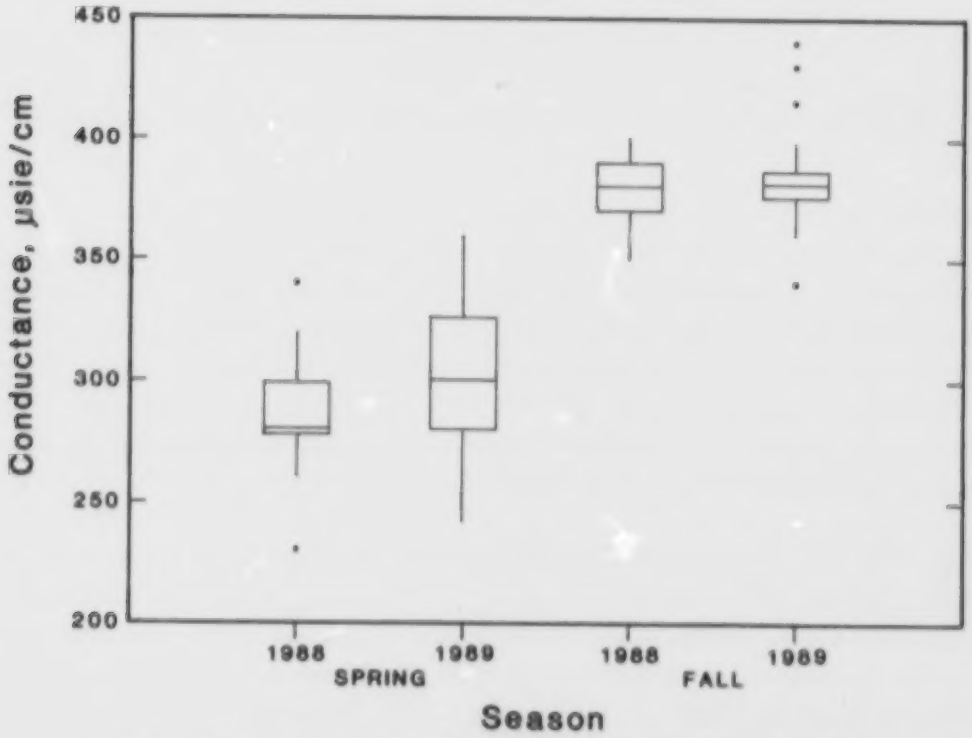


Figure 16. Seasonal Pattern of Conductance, Prairie Creek at the Mouth.

Differences between spring and fall conductance are less evident but still clear in the South Nahanni River at Nahanni Butte (Figure 17) where the flow regime is less variable.

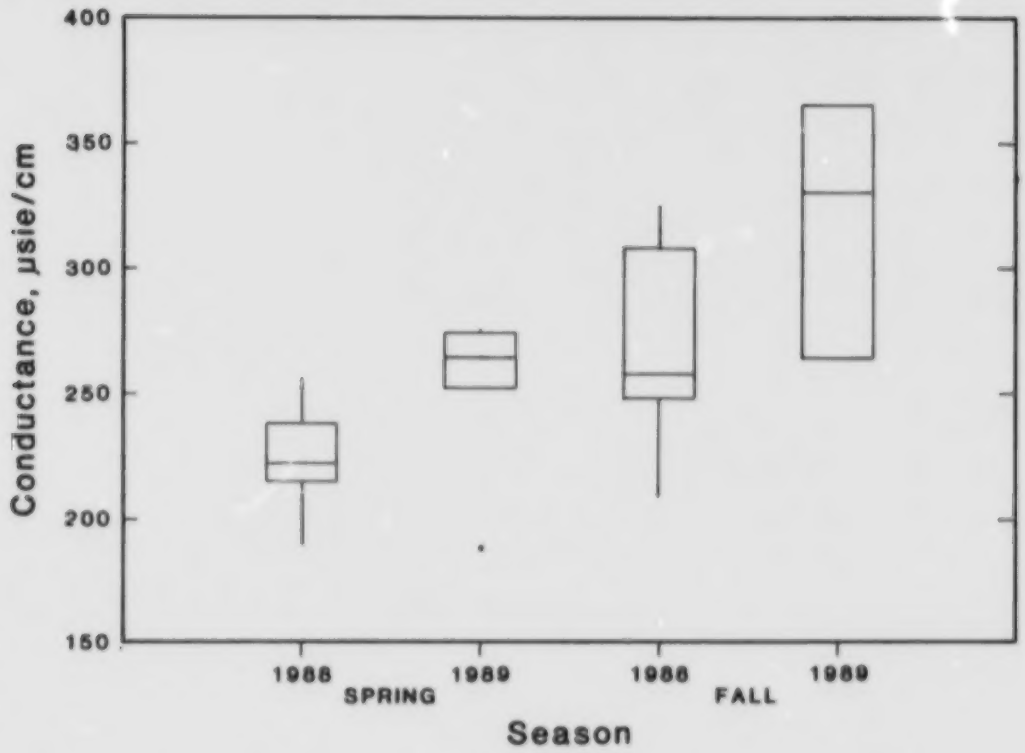


Figure 17. Seasonal Pattern of Conductance, South Nahanni River above Nahanni Butte.

Non-filterable residue is a measure of the suspended particles such as silt, clay and organic matter which are found in suspension. The South Nahanni River basin has large deposits of former glacial lake bed silts and clays in its valleys. These are easily eroded and supplied to the river as suspended load. The load settles on the river bottom and banks during low flow and is re-suspended by higher flows. The June - July flow peak in the Flat River is clearly reflected by the non-filterable residue peak (Figure 18). Prairie Creek, having a much smaller supply of erodible material due to its flow through a resistent canyon, shows a considerably less dramatic difference between high and low flow sediment levels (Figure 19).

The relationship between suspended particulates and flow is not as close as it is between conductance and flow. Factors such as frozen banks at the start of spring high flows, bank slumps unrelated to flow, rainfall events causing localized sediment contributions and variable particle sizes remaining in suspension for different lengths of time affect the relationship. The turbid matter is largely inorganic and settles out rapidly in quiet waters.

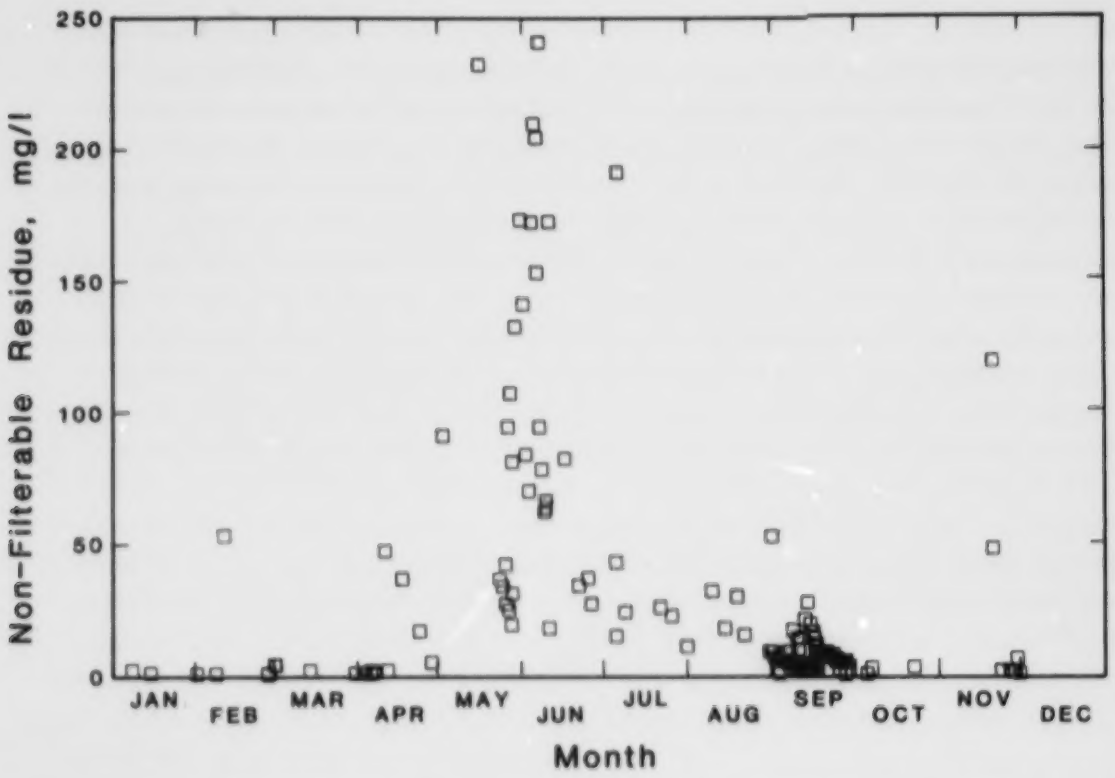


Figure 18. Seasonal Pattern of Non-Filterable Residue, Flat River near the Mouth, 1972-1990.

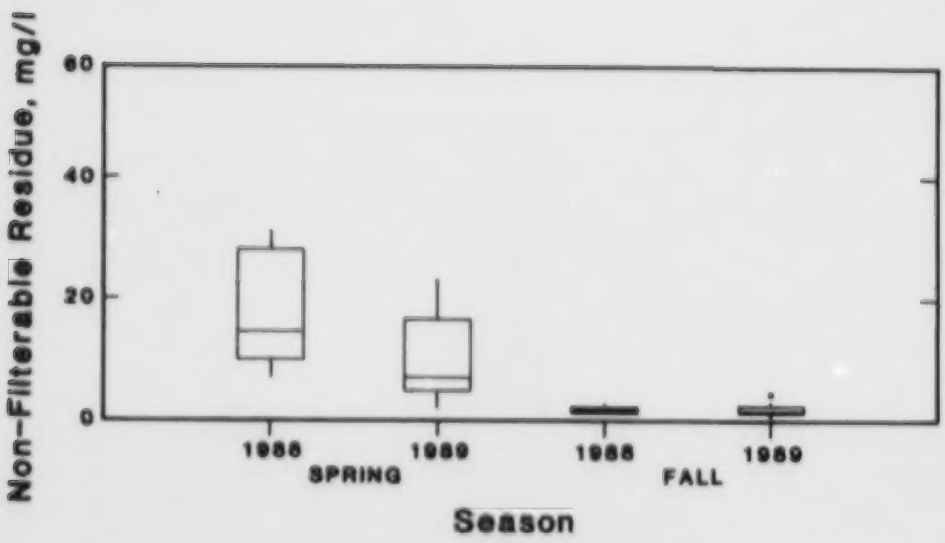


Figure 19. Seasonal Pattern of Non-Filterable Residue, Prairie Creek at the Mouth.

Under natural conditions, metals can be found dissolved in the water or attached to solid matter. The chemistry of the metal and the ambient physical and chemical conditions determine the phase. Most of the metals, particularily iron and manganese, are transported almost entirely in association with solids. For example, metals such as copper, mercury, chromium and lead also exist largely in the particulate phase. Selenium and arsenic, on the other hand, exist predominantly in the dissolved state. Metals in the dissolved phase shift in equilibrium toward the solid phase; this occurs along the course of the river under regular flow conditions. The exchange of metals from the solid-associated to the dissolved phase may be caused by a change in factors including pH, salinity or oxygenation.

The seasonal pattern of metal concentration depends upon whether the metal occurs in the dissolved or extractable phase. Changes in the total concentration and in the proportion of metals in the dissolved or solid-associated state occur over the year, reflecting changes in the source of the metals, the flow and sediment regimes and biological uptake. Metals introduced from point sources, such as a mine or a municipality, are diluted during high flow conditions. Metals from natural souces, such as bank erosion, may be increased or diluted as metals are mobilized from the drainage basin in solution and in association with mineral and organic solids.

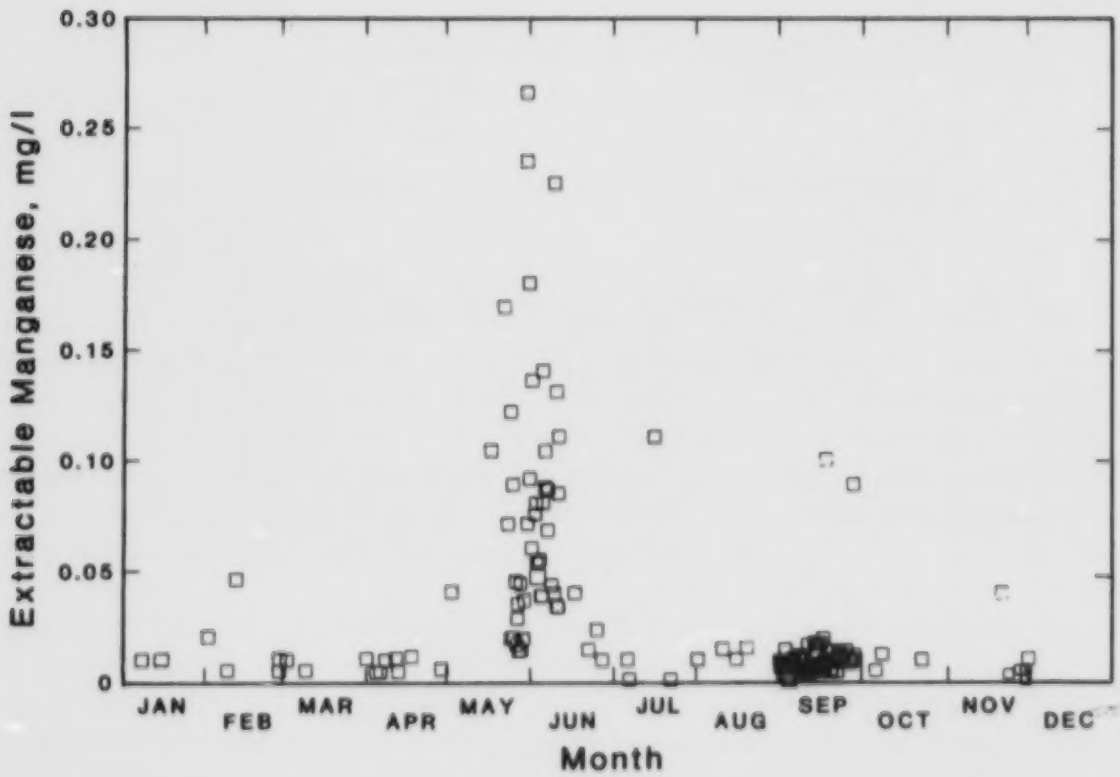


Figure 20. Seasonal Pattern of Extractable Manganese, Flat River near the Mouth, 1972-1990.

Dissolved concentrations of metals tend to be highest during periods of low flow and therefore low sediment concentration. Metals essential for biological activity, for example copper and manganese, may decline in the dissolved phase as the available fraction is assimilated during the period of biological productivity.

Metals associated with solids increase in spring along with the flow and sediment levels (Figures 20, 21). Concentrations during the rest of the year remain low, but respond to short term fluxes in the sediment regime during summer and fall (Figure 21). This seasonal pattern is evident in the South Nahanni River at Nahanni Butte (Figure 22) which expresses the sum of metals throughout the basin, and in Prairie Creek (Figure 23) where metal concentrations are extremely low. In each case the concentration and variability of the metals is highest in the spring.

Nutrients include elements such as nitrogen, phosphorus and carbon in various chemical forms. Several of the nitrogen and phosphorus forms are essential for the growth of plants, and seasonal cycles therefore tend to mirror periods of productivity. For example, orthophosphate and nitrite/nitrates (Figure 24), required by plants during the growing season, decline in concentration during summer and fall. This decline reflects not only biological uptake, but also dilution and flushing of the compounds from the system. Particulate-associated nitrogen and phosphorus are at low levels over winter and peak in spring.

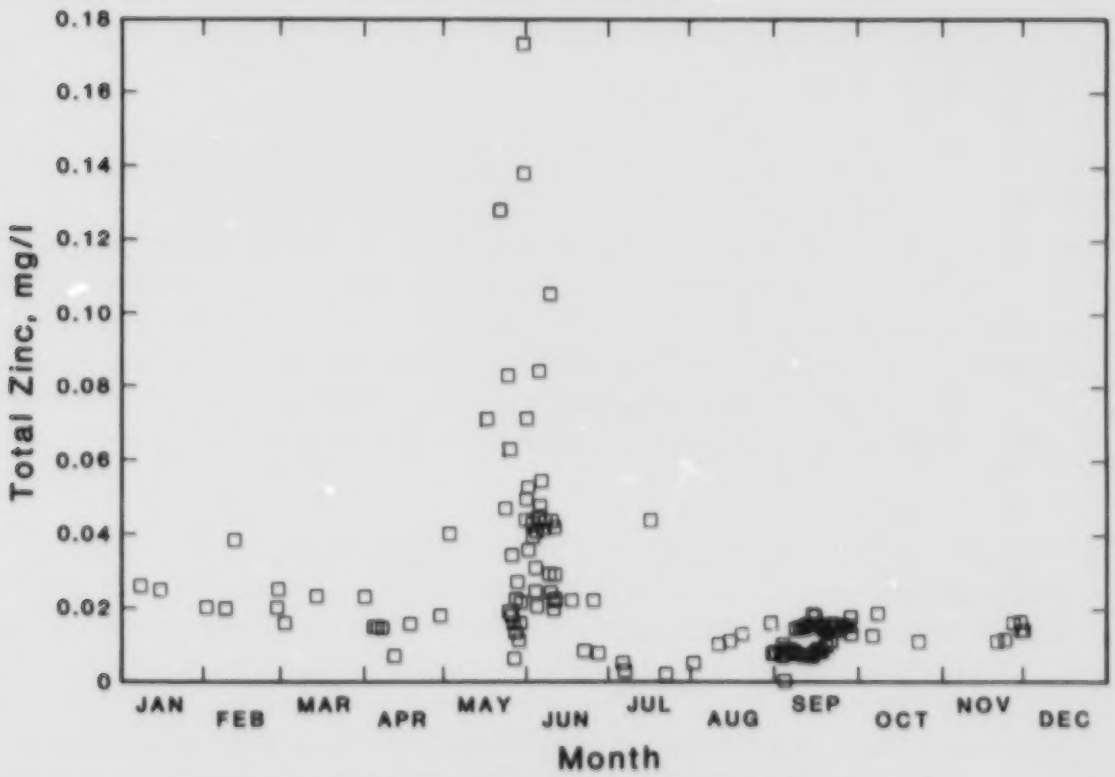


Figure 21. Seasonal Pattern of Total Zinc, Flat River near the Mouth, 1972-1990.

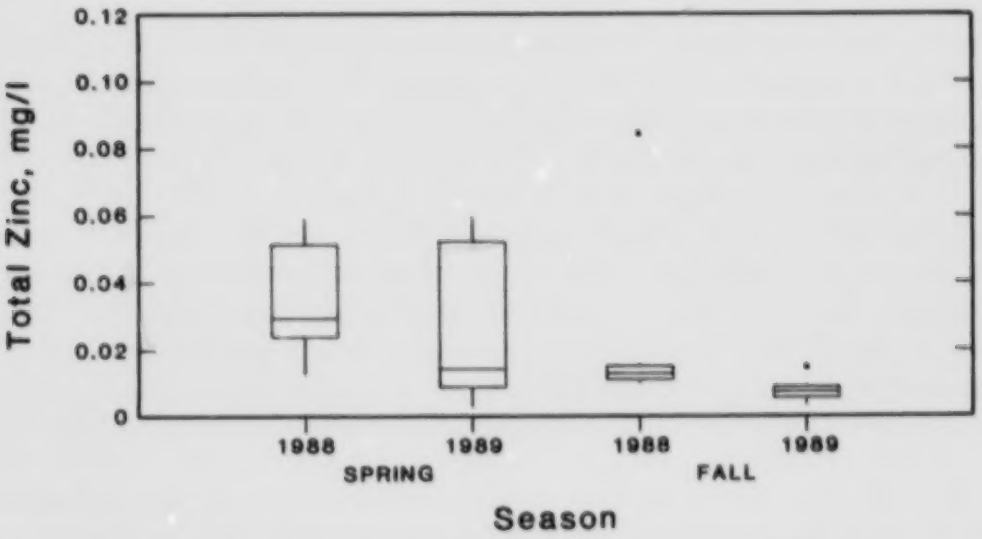


Figure 22. Seasonal Pattern of Total Zinc, South Nahanni River above Nahanni Butte.

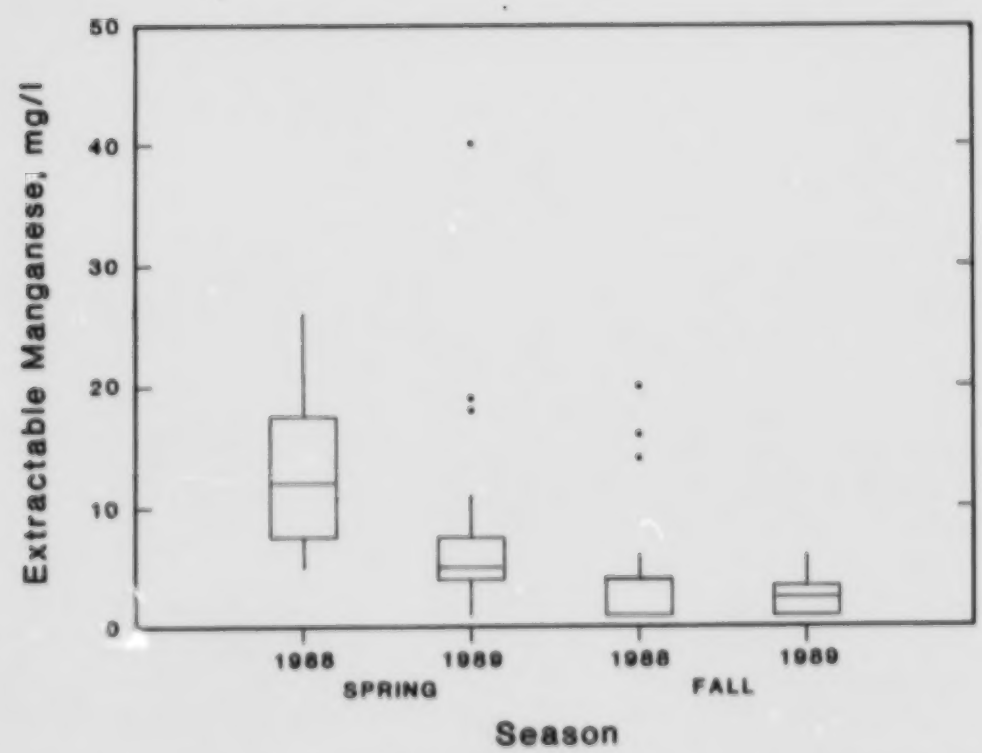


Figure 23. Seasonal Pattern of Extractable Manganese, Prairie Creek at the Mouth.

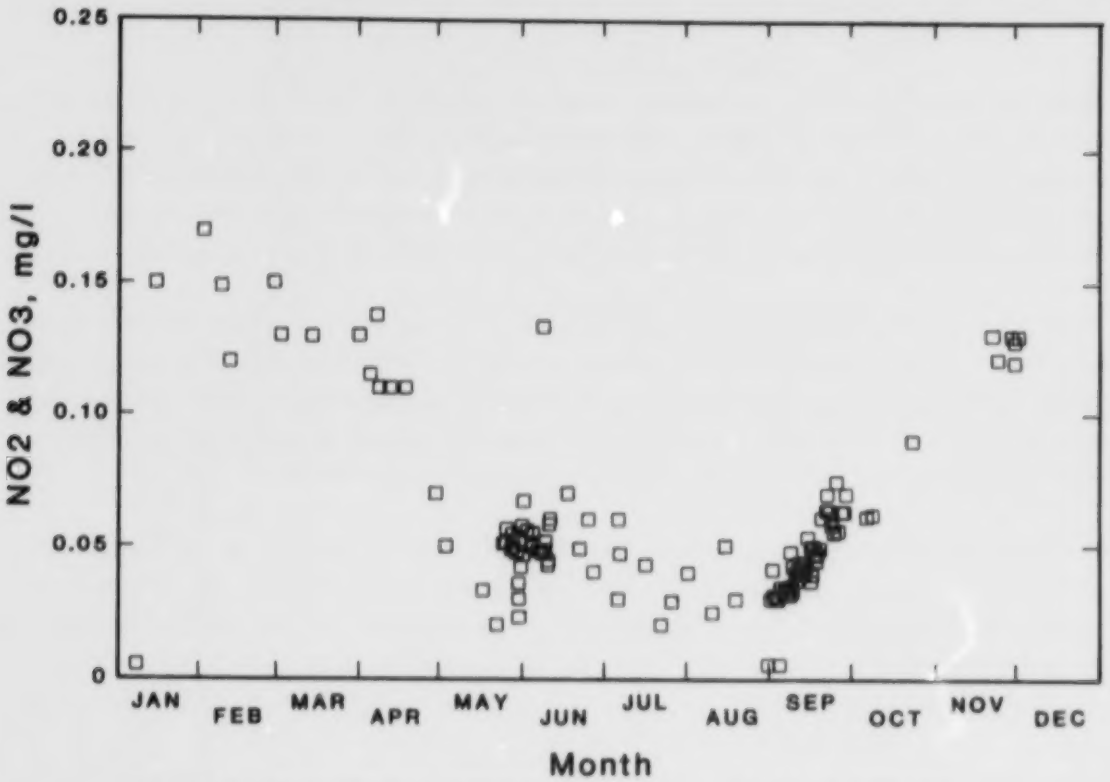


Figure 24. Seasonal Pattern of Nitrite/Nitrates, Flat River at the Mouth, 1972-1990.

4.3 Significance of Metals

Metals comprise a group of water quality parameters that can pose a threat to the health of the aquatic system. The concern over metals in the aquatic environment relates to the toxicity of metals to organisms, the potential for bioaccumulation in the food chain and hazards to human health. Existing levels of metals in the South Nahanni River basin are very low and are likely from natural sources. An increase in mining activity in the basin could increase the concentrations of metals in the water, thereby adversely affecting the resident biota that are adapted to natural levels.

The impact of metals upon the aquatic environment is largely determined by their availability to aquatic life. Physical and chemical characteristics of the metals in the dissolved and particulate states and chemical properties of the water influence the toxicity of the metals. For example, metals tend to be more readily available for biological uptake from the dissolved phase. Although sediment-related metals can be directly ingested, they are of more biological importance in their role as regulators of elements in the dissolved state. This is carried out by physical and chemical interchanges between the particulate and solute phases.

Many metals are required physiologically by aquatic organisms. Accumulation of the metals in concentrations exceeding biological requirements, however, may have toxic effects on the organism. Excessive quantities of metals in organisms may impair reproduction and retard the growth and maturation of juveniles. Shorter lifespans of the exposed organisms, decreased viability of populations and reduced species diversity have adverse effects on the ecosystem.

A major concern regarding the presence of metals in water and consequent accumulation by the flora and fauna is the magnification of metal concentrations in the food web. The upper trophic levels, which include man, may receive highly elevated concentrations of metals that may only have been present in aqueous form at low or undetectable concentrations. Human exposure to high metal levels may cause neurological and physiological impairment.

Current metal concentrations in the South Nahanni River and its tributaries do not appear to be of concern. Levels in water are almost all below water quality guidelines for the protection of aquatic life (Appendix III), indicating that existing concentrations are not a threat to the health of the aquatic ecosystem. Metal concentrations in fish tissue collected from the Flat River are not significantly above background levels, indicating no threat for human consumption (Wickstrom and Lutz, 1981). Metal concentrations on suspended sediments collected as part of the 1988-1989 study are presented in Table 4. While these data can not be interpreted at this time due to lack of particle size information and sediment guidelines for the protection of aquatic life, they do serve as a baseline for present conditions.

TABLE 4. Total Metal Concentrations on Suspended Sediments

All values in milligrams per kilogram (mg/kg) # coarse sample • fine sample, by observation < less than

Sample	Aluminum	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc	Arsenic	Selenium	Molybdenum	Cadmium	Lead
S. Nahanni River above Nahanni Butte														
June 15, 1988	60 300	147	44.6	328	27 300	<20	41.3	30.3	174	15.7	1.0	<100	<10	<50
June 12, 1989	56 000	112	45.3	296	26 000	21.1	32	50.2	209	22.6	1.5	<100	<10	<50
Sept. 11, 1989#	50 100	166	48.4	390	24 300	<20	45.7	40.5	187	39.8	3.9	<100	<10	56.9
Sept. 11, 1989•	99 700	315	98.4	672	48 300	<20	106	182	426	51.1	2.0	<100	<10	66.9
S. Nahanni River above Flat River														
June 13, 1988	58 500	155	49.4	403	29 800	35.0	56.1	34	237	15.6	0.7	<100	<10	<50
June 8, 1989	48 400	167	33.0	214	22 100	<20	66.9	49.7	95.3	107.3	5.1	<100	<10	<50
Sept. 5, 1989	73 600	227	74	537	33 000	<20	57.1	43.9	241	40	0.9	<100	<10	83.1
S. Nahanni River above Rabbitkettle River														
June 12, 1988	68 800	117	55.5	559	35 000	26.2	60.3	45.0	243	7.1	0.3	<100	<10	<50
June 7, 1989	79 600	189	58.0	504	35 400	41.0	97.4	34.9	312	22.0	1.0	<100	<10	<50
Meilleur River near the mouth														
June 14, 1988	69 800	258	90.4	130	33 700	36.1	66.4	50.6	249	19.5	2.7	<100	<10	<50
June 14, 1988	62 200	245	58.6	211	28 400	29.7	60.1	25.9	209	16.3	2.4	<100	<10	<50
June 8, 1989	58 400	311	87.4	125	31 500	<20	50.0	63.5	276	21.8	2.7	<100	<10	<50
Sept. 6, 1989	70 000	264	82.6	354	31 400	<20	72.3	34.1	244	17.1	1.0	<100	<10	<50
Flat River at the mouth														
June 13, 1988	74 400	209	66.3	409	39 900	31.0	38.6	55.6	239	18.9	1.0	<100	<10	<50
June 9, 1989	68 900	176	62.7	440	36 200	<20	31.7	53.0	272	16.9	0.6	<100	<10	<50
June 9, 1989	83 100	277	87.0	522	41 900	28.7	49.6	68.6	342	29	1.5	<100	<10	<50
Sept. 6, 1989	64 800	183	61.3	527	32 400	<20	72.8	424	342	34	1.7	<100	10.6	86.3

5.0 WATER QUALITY PROTECTION

5.1 Background

Water quality objectives are a commonly used tool, in Canada and abroad, for managing ambient water quality so that the water is not degraded and is of suitable quality for all present and future uses. Water quality objectives are concentrations which are established to support and protect a designated use at a specific site (Canadian Council of Resource and Environmental Ministers (CCREM), 1987). They are developed by different methods depending on the need for objectives, the issues and the parameters of concern, the amount of available data and a host of other factors. The approach used to develop water quality objectives is tailored to suit the needs of the water body concerned and the purposes of the responsible water management agency (Blachford, 1988).

A framework for the development of water quality objectives (Figure 25) generally involves the identification of water quality issues in the subject area, selection of key water quality parameters and examination of available water quality data and water quality guidelines. Guidelines, or numerical concentrations recommended to support a designated water use (CCREM, 1987), provide the basic scientific information for the establishment of objectives. Water quality objectives are then recommended which are deemed to be protective of sensitive water quality uses. By protecting the most sensitive water use, all other uses are also protected. Water quality objectives are usually developed to protect aquatic life as aquatic organisms are often the most affected by the presence of substances in water at a given level.

Field verification is a recommended step in the water quality objective development process. This ensures that the chosen values adequately protect the identified uses in the physical environment. The mere development of water quality objectives does not ensure non-degradation of the resource. Rather, water quality monitoring must also take place. Results of the on-going monitoring must be reviewed on a routine basis, and the results compared to the objectives. If the data exceed the objectives, the cause, extent and severity of the exceedance must be investigated. Action can then be taken to address the cause of the unusual water quality values.

The water quality objectives must also be reviewed on a routine basis. New scientific information must be incorporated into the objectives as it becomes available. New water uses, or a change in priority of existing water uses, must be taken into account. The need to develop objectives for additional water quality parameters, should new concerns arise, or to drop or modify existing objectives must also be considered. On-going evaluation is required to ensure that the objectives are protecting the resource.

Figure 25. Framework for Development of Water Quality Objectives.

Water quality objectives have been developed for ambient water environments at many locations throughout Canada and in other countries, but not for northern environments. Our knowledge of northern ecosystems is not as complete as it is for temperate environments, so the assumptions we make to protect them are less well founded. Nevertheless, the scientific knowledge base from which objectives are developed is substantial, and the fact that it was not specifically compiled for the north should not limit its application.

Water quality objectives are in place in two national parks in western Canada to assist in the protection and management of the park waters. Objectives for Prince Albert National Park were developed to provide benchmark values for the maintenance of pristine conditions, and for protection of contact recreation and fish consumption (Canadian Parks Service, 1989; Blachford, 1988). The objectives are expressed as maximum values and are specific for each lake and lake area.

Water quality objectives for Waterton Lakes National Park were developed to protect the resource with minimal interference to the natural processes as stated by the Parks Policy. Objectives are expressed as ranges of values, characterizing historic water quality conditions, which reflect the intrinsic variability of the water quality parameters that must be preserved to achieve the goal of sustainable resource use (Blachford, 1990). The values apply to each of the main lakes.

5.2 The Approach

A unique approach was adopted for the development of water quality objectives in Nahanni National Park Reserve. The approach is based upon the need to comply with Parks policy, which states that natural resources will be managed with minimal interference to the natural processes, and with the Park management plan, which states that Park waters must be protected to ensure that no unnatural change in Park water quality occurs. It is also based upon the reality that existing and future mining activities upstream of the Park boundaries could seriously alter the historic water quality regime and the life processes that depend upon it.

To address the above needs, a two level approach was developed for the Park. A long term objective is required that characterizes existing, or unspoiled, water quality conditions. Deviations from the long term objectives will be a warning that the status of water quality in the Park is changing.

Short term objectives are required to protect the Park waters, and particularily the aquatic biota, from large deviations in water quality conditions that are limited in duration. Aquatic organisms can be stressed by short term water quality concentrations that are outside the

naturally-occurring range, or near the high or low ends of the natural range for longer periods of time than occurs during regular seasonal cycles. Short term protection is a concern due to the possibility of accidental or planned releases from mining and related activities.

5.3 Water Quality Objectives

The water quality objectives developed for Nahanni National Park Reserve are presented in Table 5.

Water quality objectives were developed for five sites in the basin. The South Nahanni River upstream of Rabbitkettle River and the Rabbitkettle River define the water quality for the Park; both have mining claims in their headwaters. The Flat River at the mouth (upstream of the confluence with the South Nahanni River) is a major inflowing tributary and has considerable mining claims in its basin (specifically in the Caribou River sub-basin) as well as the Canada Tungsten Mine site. Prairie Creek has the infrastructure for Cadillac Mine. The South Nahanni River above Nahanni Butte is the most downstream site in the basin; water quality at this site represents the quality leaving the Park.

The long term objectives are the average value for each parameter over the period of record. For the Flat River, the values represent data collected from 1972 to 1990. For the other four sites, the values are averages from the 1988-1989 study. These values were selected as appropriate long term objectives due to the following characteristics of the data:

* The 1988 and 1989 study years appear to be typical. This observation is based upon the comparison of the discharge records for the study years to the long term record for the Flat River at the mouth (Figure 26). The discharge in 1988 is slightly above and the discharge in 1989 is slightly below the historic mean discharge. Water quality values are strongly governed by discharge, particularly in an environment where external influences are expected to be minor. Therefore it can be assumed that the water quality of the study years is typical of the long term quality since the study year discharge is typical of the long term discharge record.

* The above assumption is confirmed by the comparison of the water quality study data to the long term water quality data for the Flat River at the mouth (Table 6). Notwithstanding the fact that the long term data represent all seasons and the study data represent only spring and fall conditions, the data are comparable. This suggests that the study data are representative of long term ambient quality.

* Almost all values on record are well below, and for many parameters orders of magnitude below, Canadian Water Quality Guidelines (1987) for aquatic life (Appendix III). Although the objectives are based upon protecting historic conditions, rather than aquatic life protection, this

TABLE 5. Water Quality Objectives for Nahanni National Park Preserve

LTO Long Term Objectives STO Short Term Objectives

Parameter			South Nahanni River above Rabbitkettle River		Rabbitkettle River at mouth		Flat River at mouth		Prairie Creek at mouth		South Nahanni River above Nahanni Butte	
			LTO	STO	LTO	STO	LTO	STO	LTO	STO	LTO	STO
Conductance		usie/cm	222	280	198	245	314	400	337	395	256	325
Non-filterable Residue			70	230	87	227	68	204	14	23	166	335
Nitrite/Nitrate		mg/l	0.04	0.05	0.08	0.10	0.07	0.13	0.12	0.14	0.11	1.77
Total Ammonia		mg/l	0.005	0.005	0.005	0.005	0.005	0.014	0.005	0.005	0.005	0.045
pH			8.1	8.4	7.9	8.2	8.0	8.2	8.4	8.8	8.0	8.3
Sulphate		mg/l	29	41	21	31	27	36	34	46	32	43
Arsenic	Dissolved	ug/l	0.50	0.50	1.74	1.95	0.50	0.8	0.50	0.5	0.50	0.7
Barium	Dissolved	mg/l	0.04	0.04	—	—	0.08	0.04	0.08	0.08	—	—
	Total	mg/l	0.08	0.08	0.08	0.14	0.08	0.19	0.08	0.10	0.08	0.19
Cadmium	Dissolved	ug/l	0.1	0.1	—	—	0.1	0.2	0.1	0.1	0.01	0.3
	Total	ug/l	0.17	0.4	0.29	0.60	0.45	0.80	0.10	0.10	0.30	0.60
Cobalt	Dissolved	ug/l	0.5	0.5	—	—	0.5	1.4	0.5	0.5	0.5	0.5
	Total	ug/l	1.0	2.3	1.0	2.2	1.2	3.0	0.5	0.7	1.6	3.3
Copper	Dissolved	ug/l	2.1	0.9	—	—	0.5	0.7	0.5	0.5	0.5	0.9
	Total	ug/l	1.8	3.9	2.1	4.9	3.1	7.0	0.8	1.8	3.7	7.3
Cyanide		ug/l	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.0	1.0
Iron	Dissolved	mg/l	0.04	0.14	—	—	0.03	0.04	0.004	0.007	—	—
	Extractable	mg/l	0.53	1.32	1.04	2.64	0.98	2.96	0.19	0.36	1.60	2.69
Lead	Dissolved	ug/l	1.0	2.0	—	—	0.7	1.3	0.7	1.9	0.7	0.9
	Total	ug/l	1.0	2.7	1.05	2.5	1.64	3.8	0.70	1.1	2.37	5.7
Manganese	Dissolved	mg/l	0.007	0.024	—	—	0.005	0.007	0.002	0.004	—	—
	Extractable	mg/l	0.028	0.058	0.037	0.087	0.036	0.100	0.008	0.019	0.067	0.106
Nickel	Dissolved	ug/l	2.90	3.9	—	—	3.17	4.5	0.46	1.0	1.11	2.4
	Total	ug/l	6.80	9.8	5.37	8.4	6.81	11.7	1.57	3.0	7.60	15.2
Selenium	Dissolved	ug/l	0.50	0.95	1.21	1.75	0.59	0.80	0.50	1.0	0.68	1.2
Vanadium	Total	ug/l	1.1	3.2	4.6	11.3	2.2	6.1	0.5	1.4	3.9	6.7
Zinc	Dissolved	mg/l	0.016	0.499	—	—	0.005	0.009	0.001	0.002	0.002	0.007
	Total	mg/l	0.019	0.034	0.024	0.048	0.024	0.047	0.005	0.010	0.027	0.059

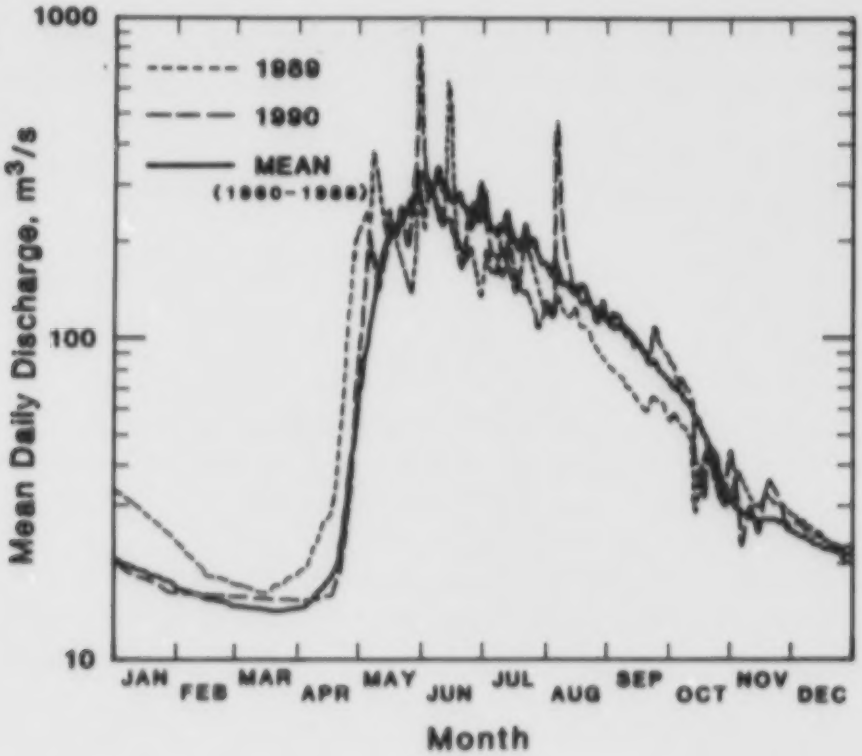


Figure 26. Historic Mean Discharge and Discharge for the Study Years, Flat River near the Mouth.

is significant as it means that the ambient quality is supportive, with a wide margin of safety, of the resident aquatic life. If the ambient quality were in exceedance of the guidelines, consideration would have had to be given to establishing water quality objectives that encourage improvement as well as protection of the ambient quality.

• Almost 50% of all water quality values for the five sites selected for objectives development are at or below the analytical detection limits. Data from Prairie Creek at the mouth are most often below the detection limits. For each parameter for the Flat River at the mouth, the percentage of values below detectable limits is shown in Table 7. For parameters with a significant percentage of values below detection, the detection limit was adopted as the water quality objective.

The short term objectives are the ninetieth percentile for each parameter over the period of record (Appendix IV). For the Flat River at the mouth, the percentiles are derived from the long term data base; for the other four sites, the percentiles are derived from the 1988-1989 study data. The ninetieth percentile was selected in order to include almost all values on record except for outlying values. The "outliers", as they may be called, occur infrequently and can greatly extend the range of values. It is desirable to exclude the outliers from the short term objectives,

TABLE 6. Comparisons of Long Term and Special Study Data (Averages), Flat River at the Mouth

Parameter			Time Period	
			1972-90	1988-89
Conductance			314	240
Turbidity			32.8	26.6
Non-filterable Residue			68.1	73.9
Nitrite/Nitrate		mg/l	0.07	0.05
Total Ammonia		mg/l	0.007	0.007
pH			7.9	8.2
Arsenic	Dissolved	ug/l	0.56	0.55
Barium	Dissolved	mg/l	0.04	0.04
	Total	mg/l	0.09	0.10
Cadmium	Dissolved	ug/l	0.21	0.12
	Total	ug/l	0.45	0.33
Cobalt	Dissolved	ug/l	0.44	0.34
	Total	ug/l	1.17	1.23
Copper	Dissolved	ug/l	0.44	0.36
	Total	ug/l	3.11	3.39
Cyanide		ug/l	0.80	0.77
Iron	Dissolved	mg/l	0.02	0.02
	Extractable	mg/l	0.98	1.14
Lead	Dissolved	ug/l	0.55	0.58
	Total	ug/l	1.64	1.76
Manganese	Dissolved	mg/l	0.004	0.004
	Extractable	mg/l	0.03	0.04
Nickel	Dissolved	ug/l	3.1	2.8
	Total	ug/l	6.8	7.2
Selenium	Dissolved	ug/l	0.59	0.62
Vanadium	Total	ug/l	3.1	2.4
Zinc	Dissolved	mg/l	0.005	0.004
	Total	mg/l	0.02	0.02

TABLE 7. Percentage of Values Below Detection Limit, Flat River at the Mouth, 1972-90

Parameter		Percentage
Conductance		0
Turbidity		0
Non-filterable Residue		9
Nitrite/Nitrate		2.4
Total Ammonia		50
Sulphate		0
Arsenic	Dissolved	7.7
Barium	Dissolved	100
	Total	50
Cadmium	Dissolved	42
	Total	30
Cobalt	Dissolved	82
	Total	55
Copper	Dissolved	54
	Total	16
Cyanide		43
Iron	Dissolved	0
	Extractable	0.7
Lead	Dissolved	75
	Total	47
Manganese	Dissolved	4.4
	Extractable	17
Nickel	Dissolved	0
	Total	2.3
Selenium	Dissolved	6.6
Vanadium	Total	40
Zinc	Dissolved	0
	Total	0.7

as their purpose is to discourage occurrences, however limited in duration, that are departures from the commonly occurring values.

5.4 Interpretation of Objectives

Water quality data collected at the five sites should be compared to the water quality objectives on a regular basis to assess whether or not they are within the natural variability.

All the data collected for each parameter at each site should be averaged and compared to the long term objectives. Values from all seasons can be combined; at the minimum, data should represent spring and fall conditions. Any departure from the objectives should be noted, as over time even small departures, whether positive or negative, could be significant. To an extent, the comparison is a subjective task. For example, the objectives are based upon a limited number of years of data which, although they appear to be representative, may or may not characterize the natural variability over a longer period of time. However, they constitute the best information available at this time and should be used until more comprehensive information becomes available.

The short term objectives apply to single water quality samples. For example, a grab sample collected in July should immediately be compared to the short term objectives; the same value should then be rolled into the annual average to be compared to the long term objectives. Exceedance of a short term objective may or may not be cause for concern. Flashy rainfall events, common in summer in the Cordilleran region, could result in extremes in sediment levels at a site and therefore elevated concentrations of sediment-related metals. This would be a natural occurrence which would not require a management response in spite of exceedance of the objective. However, an exceedance which could not be explained by natural factors alone should be investigated and appropriate action taken.

5.5 Application

The water quality objectives serve as in-stream environmental targets, providing early warning of environmental conditions. The targets describe the water quality conditions that must be met at key locations throughout the Park. The objectives alert future upstream developers to the ambient water quality requirements. Developers can then design mitigative measures that will ensure operations can meet these environmental targets.

The water quality objectives will be used to ensure that Park environmental objectives are met, and to prevent environmental problems from arising. This can be done by ensuring that water quality concerns are taken into account during the project approval stage so that concerns are

addressed during the planning stage and not later when dealing with an adverse downstream water quality condition. This means working with regulatory agencies (eg. Indian and Northern Affairs Canada) during the planning and operation phases of the project to ensure that the permit, lease and license conditions will and are being met.

Upstream exploration and development activities are screened by federal and Territorial agencies such as the Northwest Territories Water Board and INAC's Regional Environmental Review Committee. Canadian Parks Service staff will participate in these screenings by ensuring that the Park water quality objectives are understood as environmental targets that must be met by any upstream activity.

The water quality monitoring strategy will be implemented to detect adherence to the objectives and to provide an indication of the state of the aquatic environment. It will be important for Inland Waters Directorate and Canadian Parks Service to participate when effluent quality standards are being established at upstream exploration and development sites during the water licensing process. The effluent standards should reflect the water quality objectives developed for the Park.

Water quality monitoring for the purpose of compliance with the objectives must continue after the closure of mine facilities. A properly planned and managed decommissioning of the facilities is of paramount importance to ensure non-degradation of Park waters. The decommissioning plans should ensure that all possible environmental hazards are identified and dealt with so that no uncontrolled contaminant sources remain after the closure. The inclusion of a decommissioning strategy into mine plans is common practice and should be mandatory for mine developments in the Nahanni watershed.

6.0 WATER QUALITY MONITORING

Our knowledge of the water resource and the strategies we develop to improve and protect it depend upon the availability of a broad water quality data base. For the South Nahanni River and its tributaries, data are required to gain a better understanding of the river system and to assess compliance with the water quality objectives.

6.1 Background

A minimal amount of water quality monitoring currently takes place in the Park. Activities are limited due to high operational costs associated with access.

Inland Waters Directorate collects water samples for water quality analysis from the Flat River at the mouth approximately six times throughout the year, as part of the Northwest Territories water monitoring program. Canadian Parks Service does not carry out any on-going water quality activities at this time.

The Department of Indian and Northern Affairs Canada has collected samples for water quality analysis at Prairie Creek and other locations sporadically to provide data for purposes of water licensing.

6.2 Required Monitoring

At a minimum, water quality in the Park must be monitored at the five sites for which water quality objectives were developed: South Nahanni River above Rabbitkettle, Rabbitkettle River above the South Nahanni River, Flat River at the mouth, Prairie Creek at the mouth and South Nahanni River at Nahanni Butte. Samples should be collected for the purposes of determining compliance with objectives, increasing our understanding of local water quality and, for the Nahanni Butte site, assessing the result of all influences on water quality in the basin.

The five sites should be accessed by helicopter and jointly sampled by staff of Inland Waters Directorate and Canadian Parks Service.

The sites should be sampled in April, June and September. April is a time of pre-break-up low flow; ground water contributions are high and suspended sediment concentrations are low. Both factors influence the concentration and aqueous-sediment partitioning of metals. June is the period of peak flow and sediments are at annual high levels. September is representative of open water low flow with relatively clear water and dissolved substances at annual low levels. Monitoring at these time periods will capture expected variations in ambient water quality.

6.3 Additional Monitoring

Additional water quality sampling should be undertaken to fill existing data gaps which limit our understanding of the river system, and to improve our level of compliance monitoring if exploration or development activities take place in the basin.

The existing low levels of metals in the basin and their accumulation in aquatic life should be investigated by collecting and analyzing suspended sediments and fish. Many metals have an affinity for particulates, especially those of smaller size. In fast moving rivers such as the South Nahanni, the particles are not likely to settle out. Therefore, suspended sediments should be collected from the South Nahanni River at Nahanni Butte every two years and subjected to metal and particle size analyses. Due to bioconcentration, metals tend to accumulate in fish flesh at levels higher that those present in the ambient water. Fish should be collected at five year intervals in downstream reaches of the basin and analyzed for metals and supporting information (eg. lipid content). The sediment and fish data would serve as baseline information and be valuable for assessing changes in levels of metals in the watershed.

The possibility of collecting snow samples in the watershed and analyzing them for metals should be investigated. Results would indicate whether and to what extent atmospheric deposition of contaminants is occurring. The National Water Research Institute, in cooperation with the Yellowknife Inland Waters Directorate office, collects snow samples from the Park annually for organic contaminant analyses; it may be possible to collect additional sample for metal analyses.

The level of monitoring effort would have to be greatly increased if mining activities re-commence in the Prairie Creek or the Flat River basins or if exploration or development were initiated anywhere in the watershed. Compliance monitoring at the water quality objectives sites on the Prairie Creek and Flat River tributaries would require an increase in monitoring frequency to, at the very minimum, monthly sampling. Year round coverage would also be important should significant exploration or development proceed. Specific sites and appropriate monitoring media, parameters and frequencies can only be planned when details of the activity are known.

6.4 Implementation Plan

The monitoring program will be operated under a Memorandum of Understanding signed between Conservation and Protection and the Canadian Parks Service. An Administrator, appointed by each party, will be responsible for the preparation and management of the Implementation Plan. This plan will define the details of the monitoring program: sampling

media and parameters, sampling frequency and sites. It will also outline the overall coordination of the program, training requirements, data processing and evaluation, and costs of sampling and analyses. The Implementation Plan covers a period of ten years. An Annual Overview Program Implementation Report will be prepared and made available to interested parties.

7.0 RECOMMENDATIONS

An increase in mining activity in the South Nahanni River Basin could have harmful effects on the quality of water and the aquatic ecosystem health of Nahanni National Park Reserve. The pristine beauty of the Park waters is a source of pride for all Canadians. Protection of the currently high water quality will require effective water management plans.

It is recommended that:

1) the water quality objectives developed for Nahanni National Park Reserve be adopted by Canadian Parks Service and Inland Waters Directorate.
The objectives should be incorporated into the park management plans and into the water management program of Inland Waters Directorate.

2) the water quality monitoring at South Nahanni River above Rabbitkettle, Rabbitkettle River above South Nahanni, Flat River at the mouth, Prairie Creek at the mouth and South Nahanni River at Nahanni Butte form the basis of water management activities in the Park.
Monitoring at these sites will provide the data essential for comparison with the short and long term objectives. This in turn will keep water managers informed on the current state of the resource and on any changes occurring over time.

3) suspended sediment and fish be collected and analyzed for metals.
The data will provide an indication of changes in concentration over time in the basin.

4) water quality monitoring be significantly expanded if exploration and development activities in the basin proceed.
Compliance monitoring for the water quality objectives will require, at a minimum, monthly sampling year round. A higher frequency at the Flat River and Prairie Creek sites should be implemented if existing upstream mining developments commence operations.

5) analytical results of snow samples collected in the vicinity of the watershed be carefully observed.

If the results show significant levels of contaminants are present in the snow, the impact on the aquatic ecosystem of the Park should be evaluated. The requirement for additional snow sample collection sites within the Park boundaries should be assessed.

6) the Flat River at the Mouth hydrometric station be jointly maintained by Inland Waters Directorate and Canadian Parks Service.

The water quantity data are essential for the interpretation of the water quality data. It is the only long term data collection site in the basin.

7) every effort be made by the Canadian Parks Service and Inland Waters Directorate to market the principle of water quality objectives to federal and Territorial agencies with responsibilities for water management.

The importance of considering the water quality objectives at the planning stage for development in the basin, and the need to respect the water quality objectives to ensure that the current pristine waters of the Park are maintained for future generations.

8.0 REFERENCES

Blachford, D.P. 1988. *A Compendium of Water Quality Objectives Development Methodologies.* Water Quality Branch, Environment Canada, Regina.

Blachford, D.P. 1990. *Waterton Lakes National Park: Towards the Protection of its Waters.* Water Quality Branch, Environment Canada, Regina.

Canadian Council of Resource and Environment Ministers. 1987. *Canadian Water Quality Guidelines.* Prepared for the Task Force on Water Quality Guidelines.

Canadian Parks Service. 1980. *Parks Canada Policy.* Minister of the Environment. Ottawa. 69 pp. QS-7079-000-EE-AZ

Canadian Parks Service. 1983. *Nahanni National Park Reserve.* Resource Description and Analysis. Section 5: Hydrology

Canadian Parks Service. 1987. *Nahanni National Park Reserve Park Management Plan.* Minister of the Environment. QS-R133-000-EE-A6

Canadian Parks Service. 1987. *The Canadian Heritage Rivers System. The South Nahanni River.* Northwest Territories (Nahanni National Park Reserve) Environment Canada. Unpublished.

Canadian Parks Service. 1988. *Nahanni National Park Reserve.* Northwest Territories. Minister of the Environment. Main Park Brochure.QS-R135-000-BB-A6

Canadian Parks Service, 1989. *Prince Albert National Park, Aquatic Resource Management Plan.* Resource Management Report 89-1P.A.

Hamilton, S.M., F.A. Michel, C.W. Jefferson. 1988. *Groundwater geochemistry, South Nahanni resource assessment area, District of Mackenzie*; in Current Research, Part E, Geological Survey of Canada,Paper 88-1E, p.127-136, 1988.

Olding, B and M. Palmer. 1989. *South Nahanni River Basin Study. Year One 1988-1989 Data Report.* Unpublished Report. NWT Programs, Inland Waters Directorate, Yellowknife.

Wickstrom, R.D. and A. Lutz. 1981. *Tungsten and Copper Analysis of Fish and Sediments from the lower Flat River, Nahanni National Park*, NWT Canadian Wildlife Service. Ms. Report 34pp.

APPENDIX I

MEMORANDUM OF UNDERSTANDING
BETWEEN
ENVIRONMENT CANADA - INLAND WATERS/LANDS
AND
ENVIRONMENT CANADA - PARKS CANADA
WATER QUALITY MONITORING - SOUTH NAHANNI RIVER BASIN

This Memorandum of Understanding (MOU) outlines procedures to be followed by Inland Waters/Lands (IWL) and Parks Canada (Parks) with respect to the implementation of baseline monitoring and the development of water quality objectives for the Nahanni National Park Reserve in the Northwest Territories. Details of the program to be carried out under this MOU are identified in Attachment 1 entitled "Water Quality Survey Design - South Nahanni River Basin" dated December 1, 1987.

PROGRAM ADMINISTRATION

The administrators of the MOU will be A.G. Redshaw, P.Eng, Chief, NWT Programs for IW/L and the Superintendent, Nahanni National Park Reserve for Parks.

WATER QUALITY SAMPLING PROGRAM

1. The sampling program will take place in the S. Nahanni River basin during the open water season of YEAR ONE -FY 1988/89. The same program will be repeated in YEAR TWO - FY 1989/90, subject to redesign based on the data results of YEAR ONE.

2. Thirteen (13) stations will be sampled for water chemistry twice during the open water season and six (6) of these stations will be sampled intensively over two (2) five (5)-day periods, for water chemistry, also during the open water season.

3. Three (3) stations, located in the upstream and central areas of Nahanni National Park Reserve will be sampled intensively over two (2) twenty (20)-day periods, during the open water season, for both water and sediment chemistry.

4. Sampling for water chemistry will take place on a weekly basis during the open water season at Nahanni Butte.

5. The implementation of the sampling program is a joint responsibility of IW/L and Parks.

MONITORING PROGRAM PRODUCTS

6. IW/L will produce a data report based on the sampling program carried out during FY 1988/89 by March 31, 1989.

7. IW/L will produce a data report based on the sampling program carried out during FY 1989/90 by March 31, 1990.

8. IW/L and Parks will jointly produce a summary report of baseline data derived from the sampling program by December 31, 1990.

9. IW/L will produce a report identifying water quality objectives to be established for major in-flowing water courses to Nahanni National Park Reserve by March 31, 1991.

10. IW/L and Parks will jointly produce a report outlining a monitoring program designed to monitor compliance with the water quality objectives established in Nahanni Park Reserve by March 31, 1991.

11. The verified water quality data produced by this MOU are public data, equally accessible by both IW/L and Parks.

FINANCIAL CONSIDERATIONS

12. The program will be carried out on a 50/50 cost shared basis between IW/L and Parks for operating costs only. As both parties to the Agreement will be involved in the actual work, there will not be cost sharing of salaries.

13. The total estimated operating costs of the program are $175,000 over a three (3) year period, broken down as follows:

Fiscal Year	IW/L	Parks
1988/89	$ 38.8k	$ 38.8k
1989/90	$ 40.2k	$40.2k
1990/91	$ 8.5k	$ 8.5k

14. The annual payment by Parks to IW/L for their portion of this Agreement is to be provided in advance as follows:
-IW/L shall submit invoices to Parks for one third of the annual payment on July 1, October 1, and January 1 of each fiscal year.

15. This MOU is a mutli-year agreement, but may be renegotiated annually after 1988/89 by exchange of letters in consideration of actual costs and price increase/decreases.

ENVIRONMENT CANADA
Inland Waters/Lands

original signed by B.M. Burns

B.M. Burns
Director General
Western & Northern Region
Conservation & Protection

dated: February 24, 1988

Date

ENVIRONMENT CANADA
Parks

original signed by W.D. Harper

W.D. Harper
Director General
Prairie & Northern Region

dated: February 11, 1988

Date

ATTACHMENT I

WATER QUALITY SURVEY DESIGN

SOUTH NAHANNI RIVER BASIN

1. Survey Perspective
2. Design Rationale
3. Survey Design
4. Logistics Overview
5. Resource Requirements

1. SURVEY PERSPECTIVE

The historical background which has led to the development of the present design has been described in previous memos and reports. IW/L recognizes the need to develop monitoring capabilities in the NWT cordillera, whereas Parks Canada has identified the establishment of pre-development water quality objectives as a priority for the protection of aquatic resources in Nahanni National Park Reserve. The infrastructure for two mines is currently in place and it is likely that additional mining will commence once international commodity prices rise for products related to this mining. There is therefore a concern that Parks Canada's goal of preserving the natural conditions of existing water quality may be jeopardized. The mutual interest in water quality monitoring in the South Nahanni River basin led to an exchange of letters between the Directors of both agencies directing the planning of a cost-shared water quality monitoring survey.

The design of the survey will provide the basis for a Memorandum Of Understanding between IW/L and Parks Canada. It is likely that other agencies will participate in the survey, however ultimate responsibility for design and implementation will rest with IW/L and Parks Canada. The IW/L responsibility rests specifically with the Regional Director General, Western and Northern Region, Regina with direct management delegated to the Chief, NWT Programs, Yellowknife.

The specific objectives of the survey are:

1. To characterize the variability of key components of the water quality regime, with the focus on parameters associated with the mining industry;

2. To develop water quality objectives for key components of the water quality regime on major streams entering Nahanni National Park; and

3. To design an on-going water quality monitoring program that can be carried out by Parks Canada to evaluate compliance with the water quality objectives.

Considerable attention has gone into the design of this survey to ensure that the objectives stated above will be met. The operational logistics were repeatedly reviewed with local IW/L, Parks Canada and DIAND staff to ensure viability and coordination. Every attempt has been made to cut costs through coordinated logistics and a sampling design that was focused closely to the study objectives.

2. DESIGN RATIONALE

The approach to designing the survey is based on a number of factors including:

1. The location of existing and probable future mining activities;
2. The major watercourses that drain from these areas into the Park;
3. The identification of key pollutants that could be generated by mining activities;
4. The likely pathways of pollutants associated with the mining activities;
5. The major periods in natural variability for these parameters in the key components of the aquatic ecosystem;
6. The necessity to develop water quality objectives for key parameters after characterization of the natural variability;
7. The imperatives of logistics when working in the cordilleran environment; and
8. The necessity to design with a high degree of cost efficiency.

Current and future development concerns were reviewed with Parks, IW/L and DIAND staff and watercourses were identified that could potentially deliver mining pollutants to the Park boundaries. A second reconnaissance flight through the basin revealed that four additional tributaries required monitoring to determine naturally-occurring metal loads entering the South Nahanni mainstem. A stream-lined parameter list was developed that focused on pollutants likely to be associated with mining activities and a few essential parameters required for over-all interpretation of the water quality data. The focus is on the metals, including arsenic and cyanide, nitrogen compounds (from blasting operations), and sulphates (from future potential acid-generation concerns). Cost per analysis for the water chemistry sampling is $110.00.

The ecosystem components selected for sampling are based on current water quality monitoring protocols. The chemistry of the water column provides the backbone for any water quality sampling program. In the case of the cordilleran environment periods of high variability can be expected to occur during the powerful spring freshet and during late summer when fall storms

generally take place in the mountains. Sampling has therefore been targeted for two 20-day surveys at these times at three (3) key sites. The intent here is to obtain a good representation of the naturally-occurring peaks, means and lows for the parameters of concern. Less intensive sampling is aimed at sites which are important but of lower priority. Additional sites will be sampled on an opportunistic basis by DIAND and WSC at a schedule of approximately 6 times per year.

IW/L has become increasingly aware over the past few years of the relevance of sampling sediments which can transport toxic metals. Due to the high energy nature of the cordilleran regime there is little need to investigate bottom sediments as there are few depositional zones in the S. Nahanni system. Suspended sediments will likely pass through the park waters however their direct contact with aquatic biota represents a concern if they are carrying toxic levels of metals. Suspended sediments will therefore be monitored at six key locations below likely mining locations in order to determine the natural carrying capacity for metals.

The goal of preserving the natural water quality of the watercourses reflects the need to preserve the quality of the aquatic biota. It would be desirable to identify exact behaviourial effects on the biota coming from particular levels of metals. This is a research question requiring considerable ecological and ecotoxicological effort, and is beyond the limits of the current proposed study.

The monitoring of the water column and sediments will provide the basic knowledge required to describe important aspects of water quality that may be affected by future mining activities. The development of water quality objectives will likely focus on the chemistry of the water column although the interpretation of the actual data may broaden this focus to include objectives for sediment as well. The water quality objectives will be designed after the first two years of data have been interpreted. They must reflect the logistical ability of Parks Staff to carry out future monitoring in the Park.

9. SURVEY DESIGN

YEAR ONE

WATER CHEMISTRY

SITES - 13 Sites
- see accompanying map schematic

PARAMETER SCHEMAS:

a. total metals, Fe, Mg, As, Se, CN, sulphate
b. NH3, NO2-NO3, NFR
c. t. metals, Fe, MG, As, Sc, CN, sulphate, NH3, NO2-NO3, NFR
d. major ions, physicals, NFR, nutrients, t. metals, Fe, Mg, As, Sc, CN

FREQUENCIES - see accompanying map schematic

1. intensive A - 3 sites for two twenty day periods - schema a
   B - 3 sites for four five day periods - schema b
2. moderate - 6 sites for two five day periods - schema c
3. opportunistic - 3 sites approximately 6 times per year - schema c
4. weekly - Nahanni Butte 16 times per year - schema c
5. basin wide - 13 sites once - schema d
6. quality assurance - 2 sites, triplicate samples and duplicate blanks - schema c

SUSPENDED SEDIMENT

SITES 6 sites
- see accompanying map schematic

PARAMETERS - t. metals, As, Se
- particle size speciation
- mineralogy

FREQUENCIES - once in spring and once in fall

YEAR TWO

Year two will be redesigned after interpretation of the Year One data. Costing and logistics have been designed in the interim as though the same or similar activities will be taking place in Year Two as in Year One.

YEAR THREE

At this point no field work is planned for Year Three. Data from the previous years will be interpreted and water quality objectives will be developed. An on-going monitoring design will be developed during this period.

4. LOGISTICS

The logistical details for the first survey, scheduled to take place in MAY/88 are presented below.

WINTER 88

- Sediment sampling gear is dropped off at Rabbitkettle Station
- food and water column sampling equipment is cached at Rabbitkettle, Flat and Prairie Creek intensive stations.

EARLY MAY 88

- sampling teams assemble in Fort Simpson

DAY 1 OF SAMPLING PERIOD

- teams travel by jet boat to intensive sites at Prairie Creek and Flat River.
- helicopter from Ft. Simpson samples Flat and Caribou River stations and then transports last team to Rabbitkettle intensive station - may require two trips.

DAY 1 - 20

- intensive water column sampling at 3 sites and moderate water column sampling at 6 sites

DAY 10 OF SAMPLING PERIOD

- helicopter from Ft. Simpson transports samples from 3 intensive sites and 6 moderate sites (all samples stored at the intensive stations) to Ft. Simpson

DAY 20 OF SAMPLING PERIOD

- fixed wing aircraft from Ft. Simpson transports sediment specialist to Rabbitkettle station and transports water samples back to Ft. Simpson
- sediment samples are taken at Rabbitkettle

Day 22
- helicopter from Ft. Simpson slings sediment sampling equipment from Rabbitkettle to Flat River station, and returns to Rabbitkettle to transport sediment specialist to Flat River station
- helicopter transports water samples from Flat River to Ft.Simpson

Day 23 - 24
- sediment samples are taken at the Flat River and Prairie Creek areas
- sediment samples, gear, all remaining gear, remaining sampling teams transported by boat to Blackstone and trucked to Ft. Simpson

8. COSTING

A. YEARS ONE AND TWO

0 SUMMARY

Travel	- to Ft. Simpson from Winnipeg, Burlington, Yellowknife		05.7
	- Ft. Simpson to sampling locations	- spring	10.0
		- fall	10.0
Analytical	- water column		27.0
	- sediment		04.0
	- contracting out adjustment		10.4
Shipping			05.3
Supplies	- containers, bottles, incidentals		02.2
	- food		01.0
Meeting	- assessment and planning		02.0
		TOTAL	**77.6**

DETAILS ON TRAVEL AND ANALYTICAL COSTS

TRAVEL

A. - transporting team members to Ft. Simpson
- from Burlington, sediment specialist, 2 trips 3.0
- from Winnipeg, biologist, 1 trip 1.5
- from Yellowknife, 2 WQB staff, 3 trips 1.2

B. - transporting team members from Ft. Simpson to sampling locations

	MODE	TIME	
DAY 1			
Ft. Simpson - Blackstone	truck	n/a	nil
Blackstone - Flat River	boat	n/a	nil
Ft. Simpson - Flat River	helicopter	1.5	0.675
Flat R. - Caribou R. return	helicopter	1.0	0.450
Flat R. - Rabbitkettle	helicopter	0.75	0.350
Rabbitket' - Flat R. return	helicopter	1.5	1.675
Rabbitkettle	helicopter	2.0	1.000
DAY 10			
Ft. Simpson - 3 stations			
Rabbitkettle, Flat Prairie return	helicopter	6.3	3.150
DAY 20			
Ft. Simpson - Rabbitkettle			
return	fixed wing	2.75	1.000
DAY 22			
Ft. Simpson - Rabbitkettle	helicopter	2.0	1.000
Rabbitkettle - Flat R. return	helicopter	1.5	0.675
Rabbitkettle - Flat R.	helicopter	0.75	.0350
Flat. R. - Ft. Simpson	helicopter	1.5	0.675
Sub-Total for one survey		SUB-TOTAL	10.0
Total for one year, two surveys		TOTAL	20.0

B. YEAR THREE

Meetings, report production, etc. - total 17.0

WATER COLUMN ANALYTICAL COSTS

FREQUENCY	NUMBER OF SITES	TOTAL SAMPLES PER SITE	PARAMETER CATEGORY **	COST PER SAMPLE	TOTAL COSTS
INTENSIVE A	3	40	A	82.00	9840
INTENSIVE B	3	20	B	26.00	1560
MODERATE	6	10	C	110.00	6600
OPPORTUNISTIC	3	6	C	110.00	1980
WEEKLY	1	16	C	110.00	1760
BASIN-WIDE	13	1	D	220.00	2860
QA/QC	2	5	C	110.00	1100
SUB TOTAL					25700
EXPECTED LAB FEE INCREASE					1285
TOTAL					26985

** PARAMETER CATEGORIES

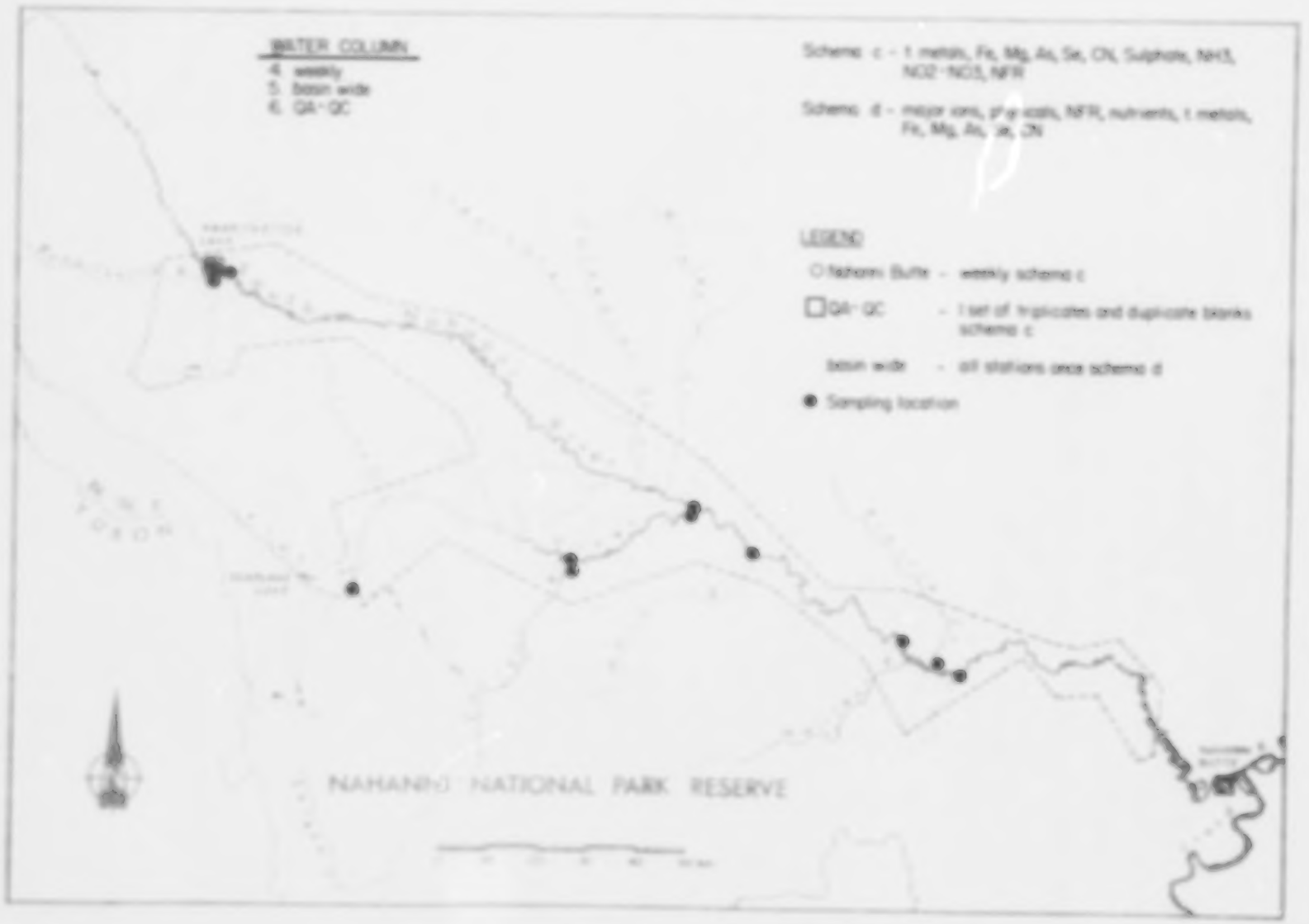
A - Total Metals, Fe, Mg, As, Sr, cyanide, sulphate
B - NH3, NO2-NO3, NFR
C - Total Metals, Fe, Mg, As, Sr, cyanide, sulphate, NH3, NO2-NO3
D - major ions, physicals, NFR, Nutrients, total metals, Fe, Mg, As, Sr, cyanide

SEDIMENT ANALYTICAL COSTS

FREQUENCY	NUMBER OF SITES	TOTAL SAMPLES PER SITE	PARAMETER CATEGORY	COST PER SAMPLE	TOTAL COSTS
Twice	6	2	Metals	307.00	3684
SUB TOTAL					3684
EXPECTED LAB FEE INCREASE					184
TOTAL					3868

NIAHANPE NATIONAL PARK RESERVE

WATER COLUMN
2. Moderate
3. Opportunistic
Scheme c - t. metals, Fe, Mg, As, Se, Cl, Sulphate, NH3, NO2 - NO3, NFR
LEGEND
Moderate - 2 to 5 day period scheme c
Opportunistic - 6 times per year scheme c
NAHANNI NATIONAL PARK RESERVE


WATER COLUMN
4. weekly
5. basin wide
6. QA - QC
Scheme c - t metals, Fe, Mg, As, Se, CN, Sulphate, NH3, NO2 - NO3, NFR
Scheme d - major ions, phys-stats, NFR, nutrients, t metals, Fe, Mg, As, se, CN
LEGEND
Nahoni Butte - weekly scheme c
QA - QC - 1 set of triplicates and duplicate blanks scheme c
basin wide - all stations once scheme d
Sampling location
NAHANNI NATIONAL PARK RESERVE

SEGMENT B ROUTE
LEGEND
NAHANNI NATIONAL PARK RESERVE

AMENDMENT 1
MEMORANDUM OF UNDERSTANDING
BETWEEN
ENVIRONMENT CANADA - CONSERVATION & PROTECTION (C&P)
ENVIRONMENT CANADA - CANADIAN PARKS SERVICE (CPS)
WATER QUALITY MONITORING - SOUTH NAHANNI RIVER BASIN

It is hereby agreed that the above Memorandum of Understanding (MOU), signed in February 1988, be amended as follows:

1) Item 12: The cost sharing formulae, for the fiscal year 1988/89, be changed from a 50/50, to a 47% C&P and 53% CPS basis.
Item 12 will now read: The program will be carried out on a 47% C&P and 53% CPS cost shared basis during the fiscal year 1988/89, and on a 50/50 cost shared basis during the fiscal years 1989/90 and 1990/91, for operating costs only. As both parties to the Agreement will be involved in the actual work, there will be no cost sharing salaries.

2) Item 13: The total estimated operating cost of the program will be changed from $175,(88) to $185,400 over the three (3) year period and based on the amendment to item 12 above, costs for the fiscal year 1988/89 will be changed from $38.8K to $41.0K for C&P and from $38.8K to $47.0K for CPS.
Item 13 will read: The total estimated operating costs of the program are $5.4K over a three (3) year period, broken down as follows:

FISCAL YEAR	C&P	CPS
1988/89	$41.0K	$47.0K
1989/90	$40.2K	$40.2K
1990/91	$ 8.5K	$ 8.5K

NOTE: CPS budget does not include salary costs
Inflation not calculated in CPS budget.

Approved by:

ENVIRONMENT CANADA
Conservation & Protection

original signed by B.M. Burns
B.M. Burns
Director General
Western & Northern Region
Conservation & Protection

dated: April 10, 1989
Date

ENVIRONMENT CANADA
Canadian Parks Service

original signed by W.D. Harper
W.D. Harper
Director General
Prairie & Northern Region

dated: March 31, 1989
Date

ADMENDENT 2
MEMORANDUM OF UNDERSTANDING
BETWEEN
ENVIRONMENT CANADA - CONSERVATION & PROTECTION (C & P)
ENVIRONMENT CANADA - CANADIAN PARKS SERVICE (CPS)
WATER QUALITY MONITORING - SOUTH NAHANNI RIVER BASIN

It is hereby agreed that the above Memorandum of Understanding (MOU), signed in February 1988, be amended as follows, in accordance with Item 15 of the MOU:

1) Item 9: The report completion data to be changed from March 31, 1991 to March 31, 1992.

2) Item 10: The report completion date to be changed from March 31, 1991 to March 31, 1992.

3) Item 13: The total estimated operating costs of the program to be changed from $185,400, over the three (3) year period, to $193,400, over a four (4) year period, and costs for the fiscal year 1991/92 to be $8,000 for report completion, printing, distribution and public relations.

Approved by:

ENVIRONMENT CANADA
Conservation & Protection

original signed by A.G. Redshaw
A.G. Redshaw
Chief, NWT Programs Branch
Inland Waters Directorate
Conservation & Protection

dated: August 12, 1991
Date

ENVIRONMENT CANADA
Canadian Parks Service

original signed by S.E. Langdon
S.E. Langdon
Superintendent
Nahanni National Park Reserve
Canadian Parks Service

dated: August 12, 1991
Date

APPENDIX II

APPENDIX II

Publications on the Water Resources of the Basin

Aitken, W. 1986. *Nahanni Butte Hydraulic Study.* For Canada-NWT Flood Damage Reduction Program. IWD Report. 10pp.

Aitken, W. and H. Westerman. 1986. *Single Station Flood Frequency Analysis, NWT.* IDW Report. 14pp. + append.

Atkinson, M.E. 1964. *A Study of Springs and Spring Deposits in the Flat River Map Area, District of Mackenzie, NWT.* Unpublished BSc thesis, UBC. 53pp.

Beak Consulting Ltd. 1981. *Prairie Creek Project. Fisheries and Invertebrate Studies, 1981.* Prepared for Cadillac Explorations Ltd. 25pp. + append.

Beak Consulting Ltd. 1981. *Prairie Creek Project. Fall Fisheries Study, 1981.* Prepared for Cadillac Explorations Ltd. 10pp.

Beak Consulting Ltd. 1982. Summary Document. *Prairie Creek Project: Water Quality and Aquatic Biology.* Prepared for Cadillac Explorations Ltd. 290pp. + tables.

Brandon, L.V. 1965. *Ground Water Hydrology and Water Supply in the District of Mackenzie, Yukon Territories and Adjoining Parts of British Columbia;* Geol. Surv. of Can. Paper 67-22. 77pp.

Brook, G.A. 1976. *The Karst Lands of the South Nahanni Region, Mackenzie Mountains, NWT.* PhD thesis, McMaster Univ. 627pp.

Brook, G.A. and D.C. Ford. 1975. *Final Report upon the Nahanni North Karst.* Prepared for Parks Canada. 386pp.

Brook, G.A. and D.C. Ford. 1978. *The Origin of Labyrinth and Tower Karst.* Nature, 275: 493-496.

Brook, G.A. and D.C. Ford. 1980. *Hydrology of the Nahanni Karst, Northern Canada, and the Importance of Extreme Summer Storms.* J. of Hydrology, 46, pp. 103-121.

Brook, G.A. and D.C. Ford. 1982. *Hydrologic and Geologic Controls of Carbonate Water Chemistry in the sub-Arctic Nahanni Karst, Canada.* Earth Surface Processes, 7(1), pp. 1-16.

Brunwell, C., J. Pritchard, G. MacLachlan, and K. Davies. 1972. *South Nahanni River above Virginia Falls.* Water Survey of Canada Report. 22pp.

Colorado School of Mines Research Institute. 1977. *Report to Canada Tungsten Mining Corporation on Water Quality Management System at Tungsten Minesite, NWT.* 34pp.

Consolidated Geotechnical Services Inc. 1986. *Report to Canada Tungsten Mining Corporation on Tailing Disposal and Reclamation, Tungsten Minesite, NWT.* 14pp + append.

Environmental Protection Service. 1977. *Brief of the Environmental Protection Service to the NWT Water Board Public Hearing on Proposed Amendments to Water License N3L3-0004 issued to the Canada Tungsten Mining Corporation.* 2pp.

Environmental Protection Service. 1977. *Results of Acute Toxicity Tests on Effluent from Canada Tungsten Mining Corporation.* Unpubl. internal report.

Ford, D.C. 1974. *Final Report on the Geomorphology of South Nahanni National Park, NWT.* Unpublished report for Parks Canada. 186pp.

Ford, D.C. and M.L. Crosbie. 1981. *Report upon Hydrological Observations in the Ram Plateau, Mackenzie Mountains, NWT.*, 1975, 1976 and 1977. Inland Waters Directorate, Environment Canada. 47pp.

Gimbarzevsky, P., J.P. Peaker, P. Addison and S. Talbot. 1979. *Nahanni National Park, NWT; Integrated Survey of Biophysical Resources.* FMI Study 1969. Parks Canada, 460 pp.

Golder Associates. 1977. *Report to Canada Tungsten Mining Ltd. on Hydrology of Tailing Ponds, Tungsten, NWT.* 33pp + append.

Golder Associates. 1979. *Seepage Studies and Proposed Alternative Backup Systems for Canamg Ltd. Tailings Ponds, Tungsten, NWT.* Unpublished report to Sigma Resource Consultants Ltd. 30pp. + append.

Golder Associates. 1980. *Tailing Storage and Mine Plant Facilities Cadillac Explorations Ltd.* Report to Kee, Preistman and Associates Ltd.

Golder Associates. 1982. *Report to Canada Tungsten Mining Corporation Limited on Hydrogeological Investigation Summer 1982, Canada Tungsten Mining Site, Tungsten, NWT.* 32pp. + append.

Hall, G.E.M., C.W. Jefferson and F.A. Michel. 1987. *Determination of Tungsten and Molybdenum in Natural Spring Waters by ICP-AES and ICP-MS: Application to South Nahanni River Area, NWT.* J. of Geochemical Exploration.

Hamilton, S.M., F.A. Mitchell, and C.W. Jefferson. 1988. *Ground Water Geochemistry, South Nahanni Resource Assessment Area, District of Mackenzie.* In Current Research, Part E, Geological Survey of Canada, Paper 88-1E, p. 127-136.

Inland Waters Directorate. 1984. *Flood Frequency Analysis for Fort Liard and Nahanni Butte.* Canada-NWT Flood Damage Reduction Program. 14pp.

Johnson, D.S. 1974. *Solution Patterns of the South Nahanni National Park and adjacent North Karst Area, NWT, Canada.* Unpublished BSc thesis, McMaster Univ. 105pp.

Kor, Preintman and Associates Ltd. 1980. *Environmental Evaluation for Cadillac Explorations Ltd. Prairie Creek Project, NWT.* 144pp.

Krivoken, L.A. 1983. *Historical Flood Review: Fort Simpson, Fort Norman, Fort Good Hope, Fort McPherson, Aklavik, Fort Liard, Nahanni Butte.* NWT Tech. Comm. Flood Damage Reduction Program. 69pp. + append.

Loeppky, K., J. Pritchard, G. MacLachlan, and K. Davies. 1972. *Flat River near the Mouth.* Water Survey of Canada Report. 20pp.

Loeppky, K., J. Pritchard, G. MacLachlan, and K. Davies. 1972. *North Nahanni River.* Water Survey of Canada Report. 9pp.

Loeppky, K., J. Pritchard, G. MacLachlan, and K. Davies. 1972. *South Nahanni River at Hot Springs.* Water Survey of Canada Report. 15pp.

MacDonald, A. 1983. *Deposited Tailings in the Flat River, NWT.* 24pp.

MacDonald, A. 1984. *Water, Wastewater and Ground Water Sampling: Canada Tungsten Mine site.* 20pp.

Moore, J.W., M.J. Hardin, and G.A. Sergy. 1978. *The Effects of Metal Mines on Aquatic Ecosystems in the NWT;* I. Canada Tungsten Mining Corporation Ltd. EPS Surveillance Rep. 5-NW-78-8. 83pp.

NWT Water Board. 1982. *Application for a Water Licence by Cadillac Explorations Ltd. Prairie Creek, NWT.* Public hearing minutes. 327pp.

NWT Water Board. 1982. *Application for a Water Licence Renewal by Canada Tungsten Mining Corporation Limited, Tungsten, NWT.* Public hearing minutes. 159pp.

Parks Canada. 1984. *Nahanni National Park Reserve Resource Description and Analysis.* Natural Resource Conservation Section, Parks Canada, Prairie Region, Winnipeg, Manitoba.

Roycroft, R.D. and D.J. Sutherland. 1975. *Cadillac Explorations Ltd., Prairie Creek Operation.* NWT Water Board, DIAND, Potential Mine Water Quality Survey Network Report Series. Water Management Section. 26pp.

Scotter, G., N.W. Simmons, H.S. Simmons and S.C. Zoltai. 1971. *Ecology of the South Nahanni and Flat River Areas.* Report prepared for National and Historic Parks Branch by Canadian Wildlife Service, Edmonton. 186pp.

Sergy, G. 1973. *A Preliminary Water Quality Investigation of the Flat River at Canada Tungsten, NWT.* EPS Surveillance Report NW-WP-73-2. 32pp.

Sergy, G., F. Zaal, and A. Boyko. 1977. *Metal Concentrations in Fishes from the Flat River at Tungsten Northwest Territories.* EPS manuscript Report NW-77-2. 22pp.

Sigma Engineering Ltd. 1983. *Alkaline Chlorinated Treatment Full Scale Pilot Test Program.* Prepared for Canada Tungsten Mining Corporation. 36pp.

Sigma Engineering Ltd. 1986. *A Review of the Ground Water Aspects Associated with Future Tailings Disposal Plans.* Prepared for Canada Tungsten Mining Corporation. 10pp.

Sigma Environmental Consultants Ltd. 1983. *Ground Water Monitoring Program 1982; Tungsten, NWT.* Prepared for Canada Tungsten Mining Corporation. 83pp.

Sigma Resource Consultants Ltd. 1976. *Aquatic Biology of the Flat River, NWT.* Prepared for Canada Tungsten Mining Corporation. 73pp.

Sigma Resource Consultants Ltd. 1976. *Flat River Study.* 35pp.

Sigma Resource Consultants Ltd. 1977. *Results of Ground Water Monitoring near Tailings Ponds at Tungsten, NWT.* (June 1976 - February 1977). Prepared for Canada Tungsten Mining Corporation. 13pp.

Sigma Resource Consultants Ltd. 1978. *Chemical Effects of Tailings Disposal on the Ground Water at Tungsten, NWT.* Prepared for Canada Tungsten Mining Corporation.

Sigma Resource Consultants Ltd. 1978. *Proposed River Engineering Program, Tungsten, NWT.* Prepared for Canada Tungsten Mining Corporation. 51pp.

Sigma Resource Consultants Ltd. 1979. *Waste Treatment Alternatives at Tungsten, NWT.* Prepared for Canada Tungsten Mining Corporation. 61pp.

Sigma Resource Consultants Ltd. 1980. *Low Flow Hydrology of the Flat River*. Prepared for Canada Tungsten Mining Corporation. 9pp.

Sigma Resource Consultants Ltd. 1983. *Ground Water Monitoring Program 1982 Tungsten, NWT*. Prepared for Canada Tungsten Mining Corporation. 81pp.

Sigma Resource Consultants Ltd, John A. Jennett and Associates Ltd. 1977. *The Spawning Ecology of Arctic Grayling (Thymallus arcticus) in the Flat River, NWT*. Prepared for Canada Tungsten Mining Corporation. 69pp.

Sigma Resource Consultants Ltd, John A. Jennett and Associates Ltd. 1978. *The Effects of Heavy Metals and Sewage on the Biota of the Flat River, NWT*. Prepared for Canada Tungsten Mining Corporation. 155pp.

Spirito, W.A., C.W. Jefferson, and D. Parr. 1988. *Comparison of Gold, Tungsten and Zinc in Stream Silts and Heavy Mineral Concentrates, South Nahanni Resource Assessment Area, Dist. of Mackenzie* In Current Research, Part E, Geol. Surv. of Canada, Paper 88-1E.

Water Survey of Canada. Miscellaneous Surface Water Data for the Study Area.

Wickstrom, R.D. 1977. *Limnological Survey of Nahanni National Park, 1975-76 Progress Report*. Canadian Wildlife Service Ms. Report 42pp.

Wickstrom, R.D. 1979. *Limnological Survey of Nahanni National Park, 1978 Progress Report*. Canadian Wildlife Service Ms. Report 22pp.

Wickstrom, R.D. and A. Lutz. 1981. *Tungsten and Copper Analysis of Fish and Sediments from the lower Flat River, Nahanni National Park, NWT* Canadian Wildlife Service. Ms. Report 34pp.

Wickstrom, R.D. in prep. *Limnological Survey of Nahanni National Park, NWT*. Canadian Wildlife Service Ms. Report.

Wood, P. and K. Loeppky. 1977. *Slope area measurement for flood of June 3, 1977 on Prairie Creek at Cadillac Mines*. Water Survey of Canada Report. 13pp.

APPENDIX III

APPENDIX III. Average Values of Parameters at Key Sites, and Water Quality Guidelines

Diss. - Dissolved

Ext. - Extractable

Parameter		Aquatic Life Guidelines *	South Nahanni River above Rabbitkettle River			Rabbitkettle River at mouth			Flat River at mouth			Prairie Creek at mouth			South Nahanni River above Nahanni Butte		
			Spring	Fall	All Samples	Spring	Fall	All Samples	Spring	Fall	All Samples	Spring	Fall	All Samples	Spring	Fall	All Samples
Conductance			178	266	222	163	234	198	192	290	240	295	382	337	237	283	256
Temperature °C			10	5.8	7.9	11.2	2.9	7.0	8.3	7.6	8.0	8.5	6.7	7.6	11.6	11.8	11.7
Turbidity			101	7.4	42	117	4.5	54	71	6.3	26	22	1.8	9.1	103	22.1	60
Non-filterable Residue			153	9.1	70	166	8.9	87	165	7.9	72	28	1.8	13.8	248	58	166
Nitrite/Nitrate mg/l			0.049	0.041	0.04	0.093	0.086	0.089	0.052	0.045	0.048	0.113	0.135	0.125	0.16	0.05	0.012
Total Ammonia mg/l		2.2 - 1.37	0.0025	0.0025	0.0025	0.003	0.002	0.002	0.012	0.003	0.007	0.003	0.002	0.003	0.016	0.017	0.016
pH		6.5 - 9.0	8.0	8.1	8.1	7.9	7.9	7.9	8.2	8.3	8.2	8.4	8.5	8.4	8.1	7.9	8.0
Sulphate mg/l			19.3	39.1	29.2	12.9	28.7	20.8	17.5	31.6	24.7	25.9	43.6	34.4	25.7	40.2	32.0
Arsenic	Diss. ug/l	50	0.4	0.04	0.04	1.78	1.70	1.74	0.65	0.45	0.55	0.19	0.20	0.19	0.48	0.58	0.53
Barium	Diss. mg/l		0.04	--	0.04	--	--	--	0.04	0.04	0.04	0.04	--	0.04	--	--	--
	Total mg/l		0.05	0.04	0.04	0.090	0.04	0.065	0.151	0.06	0.104	0.055	0.058	0.057	0.131	0.06	0.102
Cadmium	Diss. ug/l		0.100	0.052	0.075	--	--	--	0.05	0.17	0.12	0.05	0.05	0.05	0.12	0.05	0.10
	Total ug/l	0.2 - 1.8	0.29	0.079	0.169	0.44	0.15	0.29	0.57	0.11	0.33	0.10	0.05	0.07	0.40	0.15	0.30
Cobalt	Diss. ug/l		0.26	0.29	0.28	--	--	--	0.25	0.39	0.34	0.25	0.25	0.25	0.25	0.25	0.25
	Total ug/l		1.7	0.45	1.0	1.7	0.25	1.01	2.3	0.31	1.2	0.44	0.26	0.35	2.2	0.78	16
Copper	Diss. ug/l		4.0	0.25	2.1	--	--	--	0.28	0.25	0.26	0.26	0.25	0.25	0.61	0.47	0.56
	Total ug/l	2.0 - 4.0	3.2	0.77	1.8	3.64	0.67	2.15	6.34	0.66	3.39	1.3	0.29	0.82	5.0	1.8	3.7
Cyanide ug/l		5.0	0.65	0.60	0.62	0.50	0.80	0.65	0.92	0.62	0.77	0.84	0.73	0.79	0.75	0.81	0.77
Iron	Diss. mg/l		0.041	--	0.04	--	--	--	0.02	0.02	0.02	0.004	--	0.004	--	--	--
	Ext. mg/l	0.3	0.909	0.252	0.53	1.82	0.25	1.04	2.10	0.26	1.14	0.302	0.061	0.186	2.19	0.79	1.60
Lead	Diss. ug/l		1.6	0.39	1.02	--	--	--	--	--	0.58	0.96	0.35	0.65	0.60	0.35	0.51
	Total ug/l	1.0 - 7.0	1.6	0.56	1.00	1.76	0.35	1.05	3.18	0.42	1.76	0.80	0.38	0.60	3.10	1.37	2.37
Manganese	Diss. mg/l		0.0075	--	0.007	--	--	--	0.003	0.005	0.004	0.001	--	0.001	--	--	--
	Ext. mg/l		0.049	0.012	0.028	0.066	0.009	0.037	0.076	0.014	0.043	0.012	0.003	0.008	0.09	0.03	0.067
Nickel	Diss. ug/l		2.4	3.4	2.9	--	--	--	1.74	3.42	2.83	0.56	0.36	0.46	1.3	0.75	1.11
	Total ug/l	25 - 150	8.3	5.7	6.8	6.80	3.94	5.37	10.15	4.65	7.29	2.2	0.89	1.57	9.5	5.0	7.6
Selenium	Diss. ug/l	1.0	0.40	0.79	0.59	0.74	1.6	1.21	0.54	0.71	0.62	0.35	0.85	0.58	0.54	0.87	0.68
Vanadium	Total ug/l		1.9	0.5	1.1	7.7	1.4	4.6	4.7	0.36	2.4	0.85	0.27	0.57	5.4	1.9	3.9
Zinc	Diss. mg/l		0.030	0.02	0.016	--	--	--	0.001	0.005	0.004	0.001	0.001	0.001	0.003	0.0004	0.002
	Total mg/l	0.03	0.028	0.012	0.019	0.035	0.014	0.024	0.042	0.011	0.026	0.008	0.003	0.005	0.036	0.016	0.027

* from Canadian Water Quality Guidelines, 1987

APPENDIX IV

APPENDIX IV. Ninetieth Percentiles of Parameters at Key Sites

Diss. - Dissolved

Ext. - Extractable

Parameter		South Nahanni River above Rabbitkettle River	Rabbitkettle River at mouth	Flat River at mouth	Prairie Creek at mouth	South Nahanni River above Nahanni Butte
Conductance		280	245	400	395	325
Temperature	°C	12	12	--	10	16.5
Turbidity		151.3	174	83	17.2	232
Non-filterable Residue		230	227	204	23.2	335
Nitrite/Nitrate	mg/l	0.054	0.1055	0.13	0.146	0.067
Total Ammonia	mg/l	0.0025	0.00375	0.014	0.0025	0.045
pH		8.39	8.25	8.2	8.8	8.29
Sulphate	mg/l	41	30.6	36.2	46	42.75
Arsenic	Diss. ug/l	0.0005	0.00195	0.0008	0.0003	0.0007
Barium	Diss. mg/l	0.04	--	0.04	0.04	--
	Total mg/l	0.085	0.14	0.191	0.01	0.195
Cadmium	Diss. ug/l	0.00005	--	0.0002	0.00005	0.0003
	Total ug/l	0.0004	0.0006	0.0008	0.0001	0.0006
Cobalt	Diss. ug/l	0.00025	--	0.0014	0.00025	0.00025
	Total ug/l	0.0023	0.00225	0.003	0.0007	0.0033
Copper	Diss. ug/l	0.0009	--	0.0007	0.0025	0.0009
	Total ug/l	0.0039	0 00495	0.007	0.0018	0.0073
Cyanide	ug/l	0.001	0.00125	0.001	0.001	0.001
Iron	Diss. mg/l	0.144	--	0.044	0.0074	--
	Ext. mg/l	1.32	2.64	2.96	0.359	2.69
Lead	Diss. ug/l	0.002	--	0.0013	0.0019	0.0009
	Total ug/l	0.0027	0.0025	0.0038	0.0011	0.0057
Manganese	Diss. mg/l	0.024	--	0.007	0.004	--
	Ext. mg/l	0.058	0.087	0.100	0.019	0.106
Nickel	Diss. ug/l	0.0039	--	0.0045	0.001	0.0024
	Total ug/l	0.0098	0.0084	0.0117	0.003	0.0152
Selenium	Diss. ug/l	0.00095	0.00175	0.0008	0.001	0.0012
Vanadium	Total ug/l	0.0032	0.01135	0.0061	0.0014	0.0067
Zinc	Diss. mg/l	0.0041	--	0.009	0.0021	0.0078
	Total mg/l	0.0347	0.04875	0.0474	0.0107	0.059